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ARCHIVES OF SURGERY

VOLUME 27 AUGUST, 1933 NUMBER 2

ELECTRIC SHOCK

PRESENTATION OF CASES AND REVIEW OF THE LITERATURE

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The electric current has always been a source of danger to man. Lightning alone constituted the electric danger of antiquity, responsible for many deaths by a current estimated at millions of volts and about 20,000 amperes. Apparently there were no serious effects from synthetic electricity until 1879, when a stage carpenter was electrocuted at Lyons by an alternating current of 250 volts from a Siemens dynamo and died in twenty minutes. Currents dangerous enough to kill, however, were used as far back as 1849 to light a stage in Paris. The use of electricity in the home, office and factory has increased to such a tremendous extent that energized wires now form a dangerous and intricate network, surrounding one at every turn.

FACTORS INFLUENCING THE BIOLOGIC EFFECTS OF THE ELECTRIC CURRENT

In discussing the biologic effects of the electric current, I am primarily interested in unconsciousness and burns. Shocks too small to produce unconsciousness, if not often repeated[1] are usually not important from a clinical standpoint unless accompanied by burns. The prime issue in electric shock is the unconscious victim, for here, at a moment, a life is seriously threatened or already spent. The effect which a certain current will have on an organism will depend on the following factors: (1) tension or voltage, (2) intensity or amperage, (3) type of current, (4) resistance at the points of contact, (5) path of the current and (6) individual susceptibility of the organism.

1. *Voltage.*—Death may be produced by currents of very low voltage. There are instances of death from alternating currents of 46 and 60 volts, and it is claimed that any current over 25 volts should be considered dangerous to life. On the basis of the experimental work of Prevost and Battelli and Cunningham, it is now generally conceded that, with currents alternating at ordinary rates (from 25 to 300 per minute), voltages under 220 tend to produce ventricular fibrillation

1. MacMahon, H. E.: Electrical Shock, Am. J. Path. **5**:333, 1929.

without affecting the respiratory center, those over 1,000 tend to produce paralysis of the respiratory center without affecting the heart and those between 220 and 1,000 tend to involve both the ventricles and the respiratory center. Other things being equal, high tension currents are less dangerous than low tension ones. In one series of electric accidents [2] 62.5 per cent of those who received high tension shocks recovered, whereas only 39 per cent of those who received low tension shocks recovered. It is thus apparent that the voltages in most common use are most dangerous.

2. *Amperage.*—The amperage is computed by dividing the voltage by the resistance. On experimental grounds it is held that an alternating current of from 70 to 110 ma., at ordinary frequencies, or a direct current of from 200 to 250 ma. may be fatal if passed through the chest. Currents of much greater amperage are less often fatal. An alternating current of from 5 to 8 amperes may pass through the body for many seconds without causing permanent arrest of the heart, as is shown by the phenomena attending legal electrocution. In electric accidents the amperage is difficult to determine because of the variable resistance of the body. A slowly alternating current of 30 ma. has been passed through the human chest without any effect on the heart.[3]

3. *Type of Current.*—Alternating currents are said to be from three to four times more dangerous than direct currents. Recent experiments on rats [4] do not confirm this, but one must consider that the rat recovers spontaneously from ventricular fibrillation and that mortality statistics vary with different experimental animals. However, direct currents induce a much more intense nervous inhibition and produce cardiac fibrillation in a much shorter time. In certain experiments on rats alternating current was more apt to produce hemorrhage than direct current, yet the latter was more destructive to nerve cells. Alternating currents of from 39 to 150 cycles are the most dangerous and, unfortunately, the most frequently used. As the number of cycles increases, the danger diminishes. Experiment has shown that the dog's heart is about twenty times as tolerant to an alternating current of 1,720 cycles as to one of 150 cycles; and currents of from 400,000 to 1,000,000 cycles up to 3 amperes have no bad effects. In diathermy, for example, a current of about 20,000 to 40,000 volts, from 1 to 8 amperes and 1,000,000 cycles is employed.

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2. Legge, T. M.; Ram, S.; Levy, A. G., and MacWilliam, J. H.: The Pathological Changes Produced in Those Rendered Insensible by Electric Shock and the Treatment in Such Cases, Arch. Radiol. & Electroth. **27**:1, 1922.

3. Jex-Blake: Death by Electric Current and by Lightning, Brit. M. J. **1**:425, 492 and 548, 1913. This article gives an excellent review of the subject to 1913.

4. Langworthy, O., and Kouwenhouven, W. B.: Experimental Study of Abnormalities Produced in the Organism by Electricity, J. Indust. Hyg. **12**:31, 1930.

Experiment indicates that currents from induction coils are not especially dangerous to man. Spark discharges from condensers are capable of producing fatal effects by inhibition of the respiratory center without any appreciable effect on the heart. It seems that the heart is not thrown into fibrillation by "single" shocks unless the organ is struck at the exact moment when the refractory period ends, and it may be assumed that a person may withstand a powerful "single" shock, unless the heart is struck at this transient phase of its cycle. Prevost and Battelli conclude from their experiments that with very brief shocks from condensers and induction coils (1/1,000 second) fatal effects are due, not to the pressure or intensity of the current, but to the electric energy as measured in joules.[8] In some of their experimental animals an occasional postmortem finding was loss of elasticity and retractility of the lungs, which made recovery on artificial respiration impossible. In another series, the same authors electrocuted dogs with discharges from induction coils giving sparks from 15 to 45 cm. long, and noted that larger animals were killed only by asphyxia. It was their impression that the largest coil would require a minimum exposure of two minutes to kill an adult human being and that death would occur from arrest of respiration without primary heart failure. Single discharges of appropriate energy have restored normal rhythm to ventricles of animals fibrillating experimentally from alternating or direct currents. The following cases show the ability of man to escape unharmed from contact with single high voltage discharges:

CASE 1.—A laborer working in the neighborhood of a large condenser disregarded the danger signs and was struck by a static discharge of 180,000 volts. He was rendered unconscious. Artificial respiration was given at once and he was revived in nine minutes. There were no sequelae.

CASE 2.—A lineman was working on a set of "dead" lines, consisting of three parallel wires about 1 foot (30 cm.) apart. These wires paralleled another set about 15 feet (457 cm.) away, carrying a tension of 110,000 volts. The workman received a severe shock from the current induced in the "dead" line, but was not rendered unconscious. He sustained severe burns of the chest, hands and legs.

CASE 3.—An operator of a discharge set was struck by a single discharge of 150,000 volts, and was rendered unconscious. After thirteen minutes of artificial respiration he was revived. There were no sequelae.

Whenever the flow of the electric current is broken abruptly there is generated in the circuit an electromotive force of the same direction as the original current flow. While the original current diminishes, the development of this "extra current" and its addition to the original current then present increases the total electromotive force. If, in the closed circuit, the voltage is too low or the body resistance too high to produce fibrillation, such a result may follow the action of the extra current when the circuit is broken. On the other hand, the extra

current may be life-saving. Thus, in guinea-pigs, fibrillation induced by a direct current of 550 volts can be relieved by the extra current when the circuit is abruptly broken.

4. *Resistance at the Points of Contact.*—The effect of the current on the body depends to a great extent on the resistance of the skin, since the resistance of the other tissues, with the exception of bone, is small in comparison. The resistance of the skin depends on its condition of dryness, cleanliness and thickness. In a calloused palm, for example, it may reach 1,000,000 ohms and more, but in general, the average resistance of the dry skin is about 5,000 ohms, and that of the moist skin about 1,000 ohms.[5] Thus a current of 100 volts passed through the chest through moist contacts is sufficient to reach the dangerous 100 ma. range inside the body. Perspiration reduces the resistance of the skin considerably. With saline electrodes the resistance of the skin may fall to 300 ohms, and a current of only 30 volts passed through the chest may kill by reaching the fatal amperage. Deaths have been reported from sinusoidal currents, which are slowly alternating currents of from 30 to 50 volts. A high tension current that ordinarily would fail to produce fibrillation may be reduced by a high resistance to such a level as to bring this about.

In considering the resistance of the body, the point of exit as well as the point of entrance is significant. Many accidents occur as the result of good contact with the ground. Shoes have a high resistance when dry, but when wet their resistance is so diminished that a current may traverse the body and cause death. Shoes shod with iron nails are particularly dangerous, especially when the ends of the nails have worn through the inner sole. One should remember that concrete, especially if reenforced, is a good conductor.

The area and firmness of contact are other important factors. A broad surface and firm contact permit the flow of more current at given values than smaller and lighter contacts. As a current passes through the tissues their resistance diminishes rapidly.

Whenever a current flows through a conductor, heat is generated. This varies directly with the resistance and with the square of the current. The skin is the most resistant tissue of the body and is therefore subject to a variable degree of heat at both the points of entrance and exit of the current, thus producing local burns and marks. These will be considered later.

5. *Path of the Current.*—The heart is the danger area in electric shock. The central nervous system is a secondary danger zone, but in accidental electrocutions nearly all currents which traverse the head

5. Gaby, R. E.: Electrical Burns and Electrical Shock, Canad. M. A. J. **17**: 1343, 1927.

also pass through the chest. Currents from foot to foot are never fatal per se, no matter how great the current; yet even a small current passed through the chest may cause death. Schridde,[6] in thirty-seven postmortem examinations of persons killed by currents not greater than 250 volts, found electric burns on the left hand in 90 per cent. The conductivity of different organs varies according to their chemical and physical constitution. The blood and lymph streams are the best conductors.

6. *Individual Susceptibility of the Organism Under Various Conditions.*—It has been said that an alert person can tolerate a stronger shock than one taken unawares. It has also been claimed that sleep and anesthesia protect against currents, but this has received no experimental confirmation. Recent experiments on rats[4] indicate, in fact, that the mortality is definitely greater under general anesthesia, and that the death rate increases in direct proportion to the depth of the anesthesia, other things being equal. The view that fright increases the susceptibility to the electric current[7] has not been substantiated. Experiment has demonstrated that fatigue increases the susceptibility to electricity,[8] and this was confirmed by statistics, which showed that in man the greater number of electric accidents occurred at the periods of maximum fatigue (chart).

The part played by preexisting disease in the mortality from electric shock is difficult to estimate. It is known that people with disease of the heart can withstand severe electric shocks (Jellinek).

7. *Duration of Contact.*—The more prolonged the contact the more serious the effect. This is true no matter what the type of current, the nature of the contact or the resistance.

DEATH DUE TO THE ELECTRIC CURRENT

It has long been felt that the problems of electric shock might be solved by a study of electric death. Experiment has shown that death from the electric current may occur (1) from primary fibrillation of the ventricles, (2) from failure of the respiratory center, (3) from ventricular fibrillation combined with paralysis of the respiratory center, (4) from prolonged tetanus of the respiratory musculature or (5) suddenly some time later—"Delayed Death."

1. *Ventricular Fibrillation.*—Experiment has given some valuable information regarding ventricular fibrillation. The susceptibility of

6. Schridde, H.: Death from Electric Current, J. Indust. Hyg. **8**:58, 1926.

7. Jellinek, S.: Rescue Work in Electrical Accidents, J. Indust. Hyg. **9**:214, 1927.

8. Aiello, G.: The Influence of the Vegetative Nervous System and of Fatigue on Susceptibility to the Electric Current, J. Indust. Hyg. **7**:43, 1925.

various species to the electric current is quite variable. The frog cannot be killed by any current, no matter how great, unless as the result of burns. Spontaneous recovery from electrically induced fibrillation is the rule in the rat and the rabbit, and occurs occasionally in the guinea-pig. There are, however, no cases of spontaneous recovery in the adult horse, dog or ape. Young animals recover more readily than adult ones. In the cat, direct cardiac massage will almost always restore a fibrillating ventricle to normal rhythm. In the fowl, ventricular fibrillation, once established, can be restored only by passing a current through the chest from back to breast.

By direct cardiac massage combined with artificial respiration, d'Halluin [9] restored normal rhythm to 37 per cent of dogs' hearts in

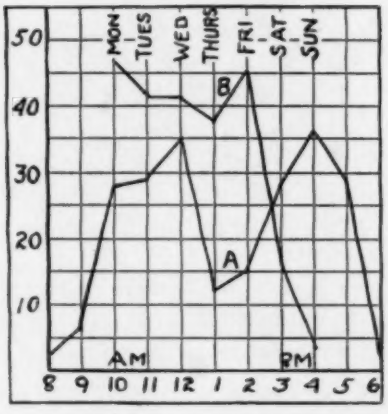

Chart showing the number of electric accidents to be greatest at the periods of maximum fatigue. (From the serial report of the Accident Prevention Committee 1927-1928. Reproduced by permission of the National Electric Light Association.) The accidents, numbering two hundred and thirty-two, occurred in inside electrical construction. *A* indicates occurrence by hours; *B*, occurrence by days.

which ventricular fibrillation had been electrically induced. Sixty-five per cent were revived by injecting into the jugular vein 4 cc. of 5 per cent potassium chloride per kilogram of body weight. The toxicity of this drug depends more on the rate of injection than on the dose. According to d'Halluin the lethal dose in dogs is 140 mg. per kilogram at 20 mg. per minute, but is 420 mg. at 4 mg. per minute. Some of the hearts in this series had been quiescent for from ten to fifteen minutes before attempts at restoration were instituted.

9. d'Halluin, M.: Lethal Power of Electricity, J. de radiol. et d'électrol. **4**:254, 1920.

Hooker, however, was able to revive dogs' hearts without the use of cardiac massage by administering potassium and calcium solutions by the arterial route. One solution consisted of 0.5 per cent potassium chloride in physiologic solution of sodium chloride to which was added 0.025 Gm. of heparin per cubic centimeter to prevent coagulation of the blood. The dose was 13 cm. per kilogram. The other solution was 0.023 Gm. of calcium chloride in physiologic solution of sodium chloride. Its dose was 15 cc. per kilogram. Fibrillation was induced and the potassium solution administered through a cannula. Needles were found to be unsatisfactory because they were too small. The heart came to rest. The calcium solution was then injected through the cannula. Normal rhythm resulted in many cases. Sometimes 1 cc. of 1:1,000 epinephrine was injected into the cannula before the calcium was administered. The femoral artery was successfully used on two occasions. Both solutions were saturated with oxygen, warmed to 37 C. and injected at a pressure of 150 mm. of mercury. Complete recovery ensued ten and one-half and twelve and one-quarter minutes respectively following the onset of fibrillation.

Wiggers [10] studied the effect of potassium chloride in relieving experimental fibrillation induced in dogs by the faradic current. The duration of untreated fibrillation was from fifteen to thirty minutes, a period much in excess of the viability of nerve centers deprived of oxygenated blood. No animals recovered spontaneously. He confirmed the effect of 5 per cent potassium chloride (in salt solution) in abolishing fibrillation in dogs, noting that the drug was most effective if injected, in equal amounts, directly into both ventricles. By electrocardiography Wiggers showed that the drug shortened the duration of fibrillation to three minutes without in any other way changing its character. If into the resting ventricles was injected a similar dose of 5 per cent calcium chloride and the heart massaged at once, coordinated rhythm could be reestablished, the heart first passing through a few minutes of idioventricular rhythm. No drug was effective without cardiac massage.

Prevost and Battelli, using dogs, succeeded in restoring fibrillating hearts to normal rhythm by passing through the organ within from fifteen to thirty seconds an alternating current of greater voltage than that used to produce the fibrillation. In quiescent hearts they were often able to produce ventricular fibrillation by direct cardiac massage

10. Wiggers, C. J.: Ventricular Fibrillation Caused by Electrical Shock: Revival by Successive Use of Potassium and Calcium Salts, Am. J. Physiol. **92:** 223, 1930; Ventricular Fibrillation Caused by Electric Shock: Revival by Successive Use of Potassium and Calcium Salts, ibid. **93:**197, 1930. Wiggers, C. J.; Bell, J. R., and Paine, M.: Ventricular Fibrillation Caused by Electric Shock, Am. Heart J. **5:**351 (Feb.) 1930.

combined with artificial respiration; then the fibrillation was changed to normal rhythm by passing a current at higher voltage through the heart.

There is a well grounded view that in man, in the majority of cases, death from electric shock occurs as the result of uncomplicated ventricular fibrillation,[11] and that fibrillation once established is usually permanent. Kerr and Bender [12] have reported a single case in which they demonstrated that recovery from ventricular fibrillation may occur spontaneously in man. Others have suggested that spontaneous recovery from fibrillation induced by electricity probably occurs frequently in man, as in some experimental animals. This, however, must be extremely rare, considering the small number of reported cases of recovery from ventricular fibrillation from other causes. In order that the patient survive, a return to normal rhythm must occur within the period that nerve centers can withstand the lack of oxygenated blood, variously estimated at from two to ten minutes. When fibrillation occurs, respirations continue, become exaggerated from asphyxia and then fail after about two minutes, death ensuing. There is no evidence of cardiac function and the patient is pale, not cyanotic.

2. *Failure of the Respiratory Center.*—When the respiratory center alone is affected the victim is unconscious, with respirations absent, but the heart continues to beat. There is a great fall in blood pressure, and the skin is cold and cyanotic. In animals, when no treatment is instituted, the heart will continue to beat for from five to eight minutes after respirations have ceased. It is probable that nervous degenerations of an irrevocable nature may not occur for an equal period following cessation of the heart beat. A similar condition may be expected in man.

In 1912 Jellinek, who had had a vast experience in electric accidents, claimed that in most cases death from electric shock was only apparent. He claimed that these victims suffered from temporary paralysis of the respiratory center and that if the blood were kept properly oxygenated by the use of artificial respiration until the normal irritability of the respiratory center returned, most of the victims would recover. Many others [13] have adopted this view. It was

11. Aiello, G.: Electricity and Man, J. Indust. Hyg. **11**:100, 1929. Legge, T. M., et al.: Pathological Changes Produced in Subjects Rendered Unconscious by Electrical Shock, Proc. Roy. Soc. Med. (Sect. Electroth.) **15**:43, 1921; Jex-Blake.[3] Legge, Ram, Levy and MacWilliam.[2]

12. Kerr, W. J., and Bender, W.: Paroxysmal Ventricular Fibrillation with Cardiac Recovery, Heart **9**:269, 1922.

13. (*a*) Report by Engineering Committee of Conference on Electric Shock; Fatal Accidents from Electric Shock in Recent Years in the United States and Canada, in England and Wales and in Switzerland, J. Indust. Hyg. **10**:111 and 117, 1928. (*b*) Harrison, B. J.: Some Considerations in Death from Electrical Shock, M. J. Australia **2**:106, 1925; (*c*) Electrical Accidents, ibid. **2**:439, 1927.

probably in cases of pure respiratory paralysis that artificial respiration accomplished its spectacular results, one patient having been revived after eight hours, and several after four hours, of so-called "suspended animation."

3. *Failure of the Heart Plus Failure of Respiration.*—When this condition occurs, the picture presented is a combination of those due to respiratory and cardiac paralysis. There is no evidence of breathing or of heart action, and the patient dies within a few minutes.

4. *Prolonged Tetanus of the Respiratory Muscles.*—During the passage of a current through the body, there is a violent contraction of all the muscles until the circuit is broken. If the current continues for many minutes, the patient will die of asphyxia, owing to his inability to use the respiratory muscles, even though the respiratory center and heart might have been capable of functioning properly had the duration of the contact been less prolonged.

5. *Delayed Death.*—Patients who have been revived sometimes die suddenly without apparent cause. This may occur minutes, hours or even days after the accident. It is thought by some to be due to sudden dilatation of the cardiac musculature and by others to be the result of hemorrhage affecting the vital centers. The following is an authentic case of delayed death:

CASE 4.—Two men were working on a "dead" line. Both were standing on the ground. A was steadying the wire with both hands, while B held the wire in his left hand and with his right was tapping a wire clamp to tighten it. Suddenly the wire became energized. Both men were thrown 15 feet, landing in the prone position. There were no injuries to the head or other parts of the body, and both men retained consciousness. A rose, walked 200 feet (61 meters) to his automobile, rode for half a mile to turn off the circuit and immediately returned. B is said to have sat still for six or seven minutes; he then rose, dusted his clothes, drew up his trousers, walked nine steps and fell dead. When A returned, his partner was dead.

LOCAL EFFECTS OF THE CURRENT

1. *Electric "Marks."*—Local changes occur at the points of entrance and exit of the current. The most interesting of these are the so-called "current marks." These are produced at the moment the body becomes energized, whether the victim survives or not, and are the same whether produced by direct or alternating current.[14] The marks are usually round or oval, varying in size from a few millimeters to several centimeters in diameter, gray to grayish yellow and slightly elevated at the edges, with a crater in the center. At the point of exit the depression

14. Jaffe, R. H.: Electropathology, Arch. Path. **5**:837 (May) 1928. A generous bibliography to 1928 is appended.

is often charred and tends to bleed. The hairs in the vicinity are not affected. The lesions are odorless, painless, free from inflammatory reaction or blisters and remain unchanged for several weeks. After a slow process of aseptic necrosis, sloughing occurs, leaving a luxurious granulation tissue, which finally forms a smooth, pink scar. The resultant slough is from two to three times the extent of the original injury. These marks are considered by some to be the most characteristic manifestations of electric shock and are especially significant when they appear in an area covered by unaffected clothing. It is probable that heat rather than electrolysis is the cause of these marks.

2. *Arc Burns.*—The flash or arc burn represents the most serious of electric burns, and occurs with light or brushing contacts. The arc has a temperature of from 2,500 to 3,000 C., and is capable of melting and volatizing bone,[14a] producing extensive lesions which may involve entire extremities. When such arcing has occurred, metallic deposits are found around and embedded in the burned area. Charring tends to minimize the general effect by reducing the flow of current through the body. In general, if the resistance at the points of contact is low, general effects are severe and burns slight; if the resistance is high, burns are severe and general effects slight. The final slough is usually more extensive than the original burn, and it is difficult to estimate the extent of the destructive process. Disintegration of the media of the arteries, without involvement of the intima, is probably responsible in part for this destruction, as well as for the occasional occurrence of hemorrhage and necrosis, even some distance from the original site of the injury.[15]

3. *Localized Edema.*—In rare instances the current produces a localized edema, which readily subsides. This may occur without the association of burns.

PATHOLOGY

In comparison with the profound clinical disturbances occurring in electric shock, postmortem evidence as to the exact mechanism involved has been disappointing. Certain changes occur, however, with unusual frequency. The vascular changes have already been noted. The arteries are sometimes so friable that ligation is impossible. Experiment indicates[16] that these effects are due to heat and not to some specific action of the current. The muscle fibers of the

14a. Lewis, Dean: Electric Burn Causing Necrosis of the Skull, Ann. Surg. **58**:149, 1918.

15. Martin: Vascular Lesions from Live Wire, J. Indust. Hyg. **6**:96, 1924.

16. Jaffe, R. H.; Willis, D., and Bachem, A.: The Effect of Electric Currents on the Arteries: Histologic Study, Arch. Path. **7**:244 (Feb.) 1929.

media, being the most sensitive part of the vessel wall, are most profoundly affected, and the cooling effect of the circulating blood protects the intima, and to a lesser degree the remainder of the wall. There is no thrombosis and no defense reaction. The blood is of a low viscosity in electric shock.

When very large currents are passed through the body, as in legal electrocutions, capillary hemorrhages are found in the brain and in the floor of the fourth ventricle. These currents, however, are far greater than those necessary to produce death. The hemorrhages in the central nervous system are not found when death is produced by smaller currents. MacMahon [1] demonstrated that destructive lesions were regularly produced in the nervous system and skeletal muscle of animals by repeated sublethal shocks. The question arises as to the possibility of permanent damage to the nervous system in those who, in their work, habitually allow electric current to pass through them. Pathologists are not in agreement as to the significance of certain other microscopic changes sometimes noted in the central nervous system. It is difficult to determine whether these minute alterations are due to artefact, postmortem changes or the effect of the current.

Albuminuria is frequent after electric shock, and usually disappears after the third day.[14] Casts may also be present. Hemoglobinuria is rather common. Jaffe thinks that the albumin and casts are due to toxic products of abnormal protein cleavage.

Few data are available regarding the effect of the current on the pulmonary system. In fatal cases hyperemia and edema of the lungs are at times present (Balthazard, Jellinek, Verse). Schridde [6] noted moderate edema of the lungs in 56 per cent of thirty-seven fatal accidents from low voltage currents. These findings have been supposed by Naville and deMoisier to be due to the original arterial hypertension, causing fluid to accumulate in the alveoli. Primary heart failure may also be a factor. The effect of the current on the lungs of those who survive the shock does not seem to be great. I know of no cases of pulmonary disease in revived persons that could be ascribed to the shock, unless as a result of artificial respiration given by mechanical respirators. It is safe to say that at the present time there are no gross or microscopic visceral lesions absolutely indicative of the passage of electricity through the organism or of death from this agent.

TREATMENT

The immediate treatment of the unconscious victim is rarely administered by a physician but usually by friends or co-workers. Linemen usually work in pairs, so that a companion, previously trained in

resuscitation, is at hand to give prompt aid in case of accident. The victim should be freed from the current at once. This may have happened spontaneously, owing to the action of certain muscles in throwing him some distance from the conductor as in case 4. Should the victim be at a considerable height from the ground, as is frequently the case with linemen, the fall alone may be the cause of severe injury or death. Again, because of unconsciousness produced by the shock, the victim may spontaneously break the circuit by falling away from the conductor. On the other hand, the action of other muscles may hold him fast to the conductor. This is especially true when the hands act as areas of contact.

The circuit may be broken by throwing the proper switch, if near at hand, or the conductor may be severed by using properly insulated instruments, such as are usually carried by electrical workers, or by using an axe with a dry, wooden handle. The current may be diverted by allowing a metal chain to make simultaneous contact with the conductor and the ground. The charged person may be dragged away from the live line by dry loose clothing or a leather belt, or pushed away by a stick of dry wood or other nonconductor. In touching the charged victim, the rescuer should use the foot, remembering that currents from foot to foot are never fatal per se, whereas those from hand to hand, or hand to foot frequently are. When the circuit is broken with an axe or other cutting instrument, the head should be turned away from the site of contact in order to protect the eyes from the flash which is frequently produced and which may be a source of danger from flash cataract for many months.[17]

CASE 5.—A lineman on a pole, whose leg was grounded through a telephone wire, contacted 4,000 volts with his ear. He fell 20 feet (609 cm.), striking his head on a heavy board. He was unconscious, not breathing, and his pulse was imperceptible. He was immediately given artificial respiration by the prone pressure method, and was revived in forty-two minutes. On the fourth day an exploratory laparatomy was performed for shock and abdominal pain. The intra-abdominal findings were normal. On the fifth day he died. Autopsy disclosed a rupture of the kidney, which was evidently the cause of death.

CASE 6.—A lineman on a pole contacted 4,000 volts with his hands. His fellow workman saw the accident and noted that the victim was unconscious and not breathing. He immediately cut the conductor, catching the victim as he was about to fall. Without attempting to lower him he began to give artificial respiration in an unusual manner. He placed the victim so that the abdomen and chest lay against the pole, and then encircled the pole and the unconscious body with his arms. By pressing and relaxing at regular intervals he induced artificial respiration. The patient was resuscitated in five minutes. Severe burns were present on

17. Franklin, W. S., and Cordes, F. C.: Electric Cataract, J. A. M. A. **85**:245 (July 25) 1925. Lewis.[14a]

the right hand and the entire left upper extremity, which later necessitated amputation of the arm. The victim recovered and the rescuer was awarded a gold medal. Had the patient fallen, he might have sustained fatal injuries.

The patient, freed from the contact, may be dazed or he may be unconscious with a normal heart action and respiration. In such cases fresh air and quiet are the only necessary therapeutic measures, with care that no mechanical obstruction to respiration is permitted the unconscious patient. The victim, however, may be unconscious and not breathing, but with the pulse still present; there may be no evidence of respiration or heart beat, or the victim may give a few gasps and then show no signs of respiration or pulse. Any unconscious victim who is not breathing should immediately be given artificial respiration, to be continued without interruption until spontaneous respirations are resumed or death is certain. Jex-Blake,[3] despite his opinion that the majority of cases are due to ventricular fibrillation, warns that "only the cooling of the body or the onset of rigor mortis should be considered as evidence of death."

The prone pressure method of Schaefer[18] is without doubt the best method of artificial respiration and superior to the mechanical devices such as the pulmotor and lung motor. It has the following advantages: It is simple, is immediately available, needs only one operator at a time, most closely simulates normal respiration and offers less danger of rupturing the lungs and blood vessels. Finton[19] has shown that the Schaefer method induces 105 per cent of the normal air exchange in deep breathing, whereas the Sylvester method induces only 35 per cent. All pressure and suction types of apparatus, in which the regulation of intrapulmonary pressure depends on the operator, no matter what his qualifications are, are dangerous and have long ago been discarded by progressive organizations. I do not doubt that many victims have actually been killed by the very apparatus applied to revive them, since there is no scientific basis of regulating the amount of force to the tolerance of the patient's delicate respiratory system.

The spectacular results of artificial respiration have been a great stimulus to the immediate use of this measure and its faithful application over a period of many hours. It is interesting that persons have been revived hours after an attending physician has pronounced them dead from electric shock, and it has even been claimed that autopsies have been performed on victims in states of "suspended animation."

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18. (*a*) Drinker, C. K.: Artificial Respiration in Electric Shock and Gas Poisoning, J. A. M. A. **83**:764 (Sept. 6) 1924. (*b*) Henderson, Yandell: Resuscitation, ibid. **83**:758 (Sept. 6) 1924.

19. Finton, W. L.: Resuscitation after Electrical Shock, J. Michigan M. Soc. **23**:544, 1924.

There is some indication, however, that the value of artificial respiration in electrical unconsciousness may have been considerably overestimated. In my experience, it has been of no avail in the majority of cases, even though given promptly, properly and faithfully by crews specially trained in the Schaefer method.

In the present series of electric accidents, numbering fifty-eight from 1922 to 1930 inclusive, fifty-three of the victims (91 per cent) died. Important additional data were available in only twenty-seven cases. These twenty-seven cases form the basis of the following deductions (table). Twenty-two patients, or 82 per cent, were rendered unconscious by the shock. In one case artificial respiration was not begun for thirty minutes and in another it was begun at once and discontinued after thirty minutes. In all other patients, in whom respirations were absent (74 per cent), artificial respiration by the prone pressure method was begun within a few minutes and continued without interruption until the victim was revived or rigor mortis appeared. In the fatal cases the minimum duration of artificial respiration was four hours and the maximum eleven and a half hours. Twenty-two patients (82 per cent) died. Of these fatalities four (15 per cent) were due to falls and burns. The remainder of the fatalities were due to the current alone (eighteen patients, or 67 per cent). Of these eighteen patients, sixteen probably died of persistent ventricular fibrillation. This represents 89 per cent of deaths due to the current alone and 73 per cent of the total deaths. Uncomplicated paralysis of the respiratory center was probably the cause of death in five patients (18 per cent). These statistics do not agree with those of Drinker and others,[18a] who reported 76 per cent of recoveries in two hundred and sixty-five cases of electric shock.

No amount of artificial respiration will restore to normal rhythm a fibrillating ventricle. None the less it is wise to give this treatment continuously if operation is inadvisable, with the thought in mind that the diagnosis may be wrong or that spontaneous recovery, should it occur, will find the most favorable conditions. I know of no case of recovery from electrically induced unconsciousness in which fibrillation of the ventricles was known to have been present, and my clinical experience confirms the impression gained by experiment, that in the majority of cases death occurs promptly from persistent ventricular fibrillation. The chief problem, therefore, in the treatment of electric shock, concerns the treatment of ventricular fibrillation.

The persons on whom the task of immediate treatment falls are unable to judge the nature of any particular case of electric unconsciousness, and in consequence each case is treated as one of respiratory paralysis. The physician, however, is better qualified to determine the

nature of the electric accident. So long as there is evidence of normal cardiac rhythm, the prognosis is good and artificial respiration should be continued. Once the diagnosis of ventricular fibrillation is certain and artificial respiration has not revived the patient within fifteen minutes after the accident, unduly prolonged artificial respiration is illogical.

The heart sounds may not be audible and the pulse not palpable, yet the heart may be beating feebly. In such cases, however, it is more likely that ventricular fibrillation has been produced. If regular pulsations are noted in the veins of the neck, and no heart movements are heard or felt, ventricular fibrillation is even more likely, as it indicates that the auricles are still functioning rhythmically. The absence of venous pulsations in the neck is not so important, for auricular fibrillation may accompany ventricular fibrillation. The diagnosis is uncertain in most cases. D'Halluin [9] suggested that a drop of ether instilled into one eye will reveal the presence of even a feeble circulation by the redness produced, the other eye serving as a control. During this test the patient should lie horizontal and all other influences which might have a bearing on the interpretation of the result should be excluded. He also suggested that a blunt probe introduced through the skin to lie directly against the ventricle would show the presence or absence of regular pulsations, or possibly the tremulations of a fibrillating heart.

The presence of ventricular fibrillation having been indicated by a careful test, the surgeon is confronted with a most grave situation. The injection into both ventricles of potassium followed by calcium,[10] and the passage through the heart of a current at higher voltage than that used to produce the fibrillation are likely to stop ventricular fibrillation in man. In order to restore regular rhythm, both of these methods require prompt exposure of the heart for direct massage, a heroic measure indeed, which must be performed before the death of the vital centers (ten minutes). The carotid route for the administration of potassium and calcium [20] has been successful in dogs without cardiac massage, and would be worth attempting in human beings. If these measures were unsuccessful, cardiac massage could be resorted to. It is therefore clear that the chance of recovery from ventricular fibrillation occurring under the conditions of electric shock is almost hopeless, practically speaking, unless the accident occurs in a hospital or operating room. In favorable cases the surgeon should not shrink from making a quick, abdominal incision and massaging the heart. One must realize that grave circumstances call for heroic action, and that, in the

20. Hooker, D. R.: Chemical Factors in Ventricular Fibrillation, Am. J. Physiol. **92**:639, 1929; Recovery of the Heart in Electrical Shock, ibid. **91**:305, 1930.

Electric Shock: Record of Cases (1925-1930)

Case	Voltage	Contact Areas	Unconsciousness	Length of Artificial Respiration	Burns	Pulse	Respiration	Additional Data	Final Result
1	4,000	Left shoulder; both feet	Immediate	5 hrs.	.....	0	0	Victim was standing on crossarm of pole	Death; never regained consciousness
2	11,000	Right hand; both feet	Immediate	4 hrs.	.....	0	0	.....	Death; never regained consciousness
3	4,000	Left arm; right leg	Immediate	1½ hrs.; until rigor mortis	Severe; 3d degree at contact areas	0	0	Rigor mortis in 1½ hours.....	Death; never regained consciousness
4	4,000	Left hand; right hand	Immediate	4 hrs.	.....	0	0	Contact made through pliers in right hand to ground wire in left	Death; never regained consciousness
5	?	Hand; both feet	Walked 7 ft., then fell unconscious	7 min.	None	+	0	Very cyanotic; supposedly dead; no sequelae	Recovery
6	4,000	Hand; both feet	Immediate	4¾ hrs.; until rigor mortis	.....	+	0	Beneficial results from use of carbogen combined with artificial respiration	Death
7	Low voltage; secondary wire from primary of 6,600	Both hands; both feet	Immediate	4 hrs.	3 pinhole-sized "marks" on hands	0	0	.....	Death; never regained consciousness
8	11,000	Both hands; left foot	Immediate	4 hrs.	.....	0	0	....	Death; never regained consciousness
9	11,000	Right arm; both legs	Immediate	0; respirations present	At contact areas	+	+	Fractures of skull and pelvis from fall	Death 10 hours later, probably from fall
10	?	Face; both feet	Immediate	4 hrs.	.....	0	0	Current traveled 20 feet, through ground to wire fence; victim contacted fence	Death; never regained consciousness
11	11,000	Both hands; knee	Immediate	4 hrs.	.....	0	0	Contact established while splicing wire; wire became energized	Death; never regained consciousness
12	440	Both hands	Not unconscious	0; respirations present	Severe; covered almost entire body	+	+ until death	Contact established while testing 440 volt fuse with lamp; clothes ignited	Death after 16 hours, probably from burns
13	4,000	Right hand; both feet	Immediate	30 min.	.....	..	0	Duration of artificial respiration not sufficient	Death

13	4,000	Right hand; both feet	Immediate	30 min.	.....			not sufficient	
14	11,000	Right hand; left hand	Unconscious after 30 sec.	2½ hrs., not begun for 30 min.	.....	+	+	Contact established through lead pencil and an electric device	Death
15	11,000	Both legs; back	Not after 1st shock immediate after 2d shock	4 hrs.	Severe at contact areas	..	..	Two successive shocks; fuse blew out at substation and substation operator reestablished current flow; victim was killed immediately	Death
16	4,000	.....	Not unconscious	0; respirations present	Severe 3d degree on upper half of body	+	+	Clothes ignited	Death 16 hours later, probably from burns
17	4,000	Right arm; right leg	Immediate	4 hrs.	None	0	0	Grounded leg through "green" (wet) pole	Death
18	11,000	.....	Immediate	2¾ hrs.	.....	..	..	.....	Death
19	4,000	Ear; leg	Immediate	42 min.	.....	+	0	Laparotomy on fourth day for shock and abdominal pain; autopsy showed rupture of kidney, probably from fall	Recovery after 42 minutes; death after 5 days from rupture of kidney
20	11,000 (?)	Both legs; precordium	Immediate	4 hrs.	Severe at contact areas	0	0	Contact with current induced in "dead" wire paralleling a similar wire carrying 11,000 volts 4 feet away	Death
21	11,000	Right heel; right arm	Immediate	11½ hrs.; until rigor mortis	.....	Slow and weak	0	Apparent death in 10 hours, when pulse became imperceptible	Death
22	4,000	Left arm; both feet	Immediate	4 hrs.	.....	0	0	"Green" pole	Death
23	? Induced from 110,000	Chest; hands; legs	Not unconscious	Respirations present	Severe at contact areas	+	+	.....	Recovery
24	?	.....	Not unconscious	Respirations present	.....	+	+	Victim thrown 15 feet; stood up, walked ten steps and fell dead	Death delayed for 10 minutes
25	?	.....	Not unconscious	Respirations present	.....	+	+	Same accident as in case 24; victim thrown 15 feet	Recovery; no sequelae
26	4,000	Both hands; left arm	Immediate	5 min. while on pole	Severe at contact areas	..	0	Severe shock for 36 hours.....	Recovery
27	4,000	Right hand; left foot	Immediate; lasted 30 min.	20 min.	Severe 3d degree at contact areas	..	0	Contact established through brace and bit through "green" pole; 8 weeks' hospitalization because of burns	Recovery; neurotic symptoms

words of d'Halluin,[9] "Un coeur qui tremule n'est pas une coeur mort [A quivering heart is not dead]."

Reports are not wanting in which quiescent or fibrillating human ventricles were revived by prompt cardiac massage. I know of no case of massage of the heart in a human subject for the relief of ventricular fibrillation induced by the electric current, yet the applicability of this procedure, combined with the use of potassium and calcium, as a method of treatment appears to be logical. The heart is best approached through an abdominal incision. The thoracic approach is more dangerous and time-consuming. The organ is grasped through the intact diaphragm. If this is not possible, the diaphragm should be incised near its costal insertion, about 1 inch (2.5 cm.) to the left of the midline and the hand introduced through the opening. The heart is grasped between the thumb and the first two fingers and gently but firmly massaged at the rate of about thirty times per minute. If available, calcium chloride may be injected into the ventricles before massage. Even if the heart is at rest, cardiac massage should be instituted, but without the use of potassium chloride. If massage of the quiescent heart produces merely a state of fibrillation, potassium and calcium should be administered as advised, and massage should be continued.

The use of stimulating hypodermics has been discouraged by those most familiar with problems of resuscitation.[21] The intracardiac injection of caffeine, epinephrine or alpha-lobeline has been looked on with favor by some.[22] Lobeline is a dangerous drug,[23] and may even cause the death of a victim who might otherwise have been revived. Caffeine is safer and more efficacious. Inhalation of oxygen alone, or air enriched with oxygen, is not advised because oxygen is not a respiratory stimulant, and may even act as a depressant. The use of carbogen (7 per cent carbon dioxide in oxygen) is of definite value not only in those cases in which respirations have become spontaneous, but also in combination with artificial respiration. Zangger, Israel and others [7] advise faradism of the phrenic nerve as a respiratory stimulant.

CASE 7.—A workman on a pole contacted 4,000 volts. He was immediately rendered unconscious. There was no evidence of pulse or respiration. He was markedly cyanotic. One and a half minutes after the accident artificial respiration was instituted and continued without interruption for about five and one-half hours. For one hour his condition remained unchanged. An inhalator arrived at about

21. McLachlan, W.: Resuscitation After Electrical Shock, Canad. M. A. J. **17**:1346, 1927. Drinker.[18a] Henderson.[18b] Finton.[19]

22. Morgan, J. G., and Amor, A. J.: Case of Electrocution With Notes on the Clinical Value of Lobeline, Lancet **1**:756, 1928. Jellinek.[7]

23. Drinker, C. K.: Acute Asphyxia as a Medical Problem, J. A. M. A. **90**: 1263 (April 21) 1928. Norris, V. H., and Weiss, S.: The Properties of Alpha-Lobeline, J. Pharmacol. & Exper. Therap. **31**:43, 1927.

this time. Artificial respiration was then combined with inhalation of carbogen. A few minutes after the use of the gas the color of the patient became quite normal and remained so for forty-five minutes. At this time the supply of carbogen became exhausted. Then the deep cyanosis returned. Fifteen minutes later a second supply of gas arrived, and immediately on using the inhalator the normal color reappeared and remained normal for another forty-five minutes, when this supply became exhausted. Then the cyanosis again returned. Unfortunately no more carbogen was available. The cyanosis continued, despite the use of artificial respiration, until rigor mortis set in about two hours later. One can only conjecture whether or not the victim would have been saved, had sufficient carbogen been available.

It has been believed that if the unconscious victim were subjected to some physical shock he would quickly recover, but experiment has not confirmed this, and "counter-shock" is now considered unjustifiable.[24] Jellinek [25] and others [26] advise lumbar puncture and drainage as a prompt therapeutic measure in cases showing signs of increased intracranial pressure. Such signs may appear at once or hours after the accident. The revived patient should immediately be hospitalized, and kept at rest for at least three weeks to guard against sudden cardiac dilatation or secondary hemorrhage and to give rest to a possibly damaged central nervous system.

Electric burns which during the first twenty-four hours appear trivial may later become serious, even fatal, from toxic absorption, secondary hemorrhage or infection. All electric burns should be treated with care. Those of the first degree may be treated with soothing ointments; in the second and third degree burns greasy ointments are not advised. The less serious second and third degree burns may be treated with radiant light and ultraviolet rays.[13c] In severe second and third degree burns treatment with tannic acid is recommended. In clean cases the coagulum usually separates at about the tenth day. If infection supervenes, an anesthetic should be given and the membrane should be removed under rigid asepsis, the wound thoroughly cleaned, all grease, scabs and débris removed and the wound treated by antiseptics or by radiant light and ultraviolet irradiation. Acriflavine base 1:5,000 is recommended by Fisher.[27] Mercurochrome-220 soluble has been discarded. Beneficial effects are said to follow the local application of

24. Campbell, A., and Hill, L.: Countershock as a Method of Resuscitation Following Electrocution, J. Indust. Hyg. **6**:267, 1924. Drinker.[18a] Finton.[19]

25. Jellinek, S.: Active Treatment of Wounds Produced by Electricity, Wien. klin. Wchnschr. **41**:766, 1928. Lumbar Puncture in Electrical Injuries, J. Indust. Hyg. **11**:80, 1929. Value of Lumbar Puncture in Electrical Shock. Internat. Clin. **1**:123, 1929; footnote 7.

26. Schneider, P.: Mechanism Involved in Death from Electrical Shock, J. Indust. Hyg. **11**:216, 1929.

27. Fisher, H. E.: Electrical Burns, Illinois M. J. **57**:201, 1930.

normal horse serum to which 0.35 per cent cresol has been added.[28] Débridement is best performed after separation of sloughs because of the confusion of fascial planes and the danger of alarming hemorrhage. Skin grafting by full thickness or pedicle grafts may be indicated when the wound is clean and healthy granulations are present.

On the whole surgery should be approached with caution, because of the tendency of the lesions to increase in size and because of the vascular injuries which may extend a considerable distance from the apparent site. On the other hand, Wells[29] recently advised prompt débridement of the burn, followed by an immediate skin graft, claiming that the convalescence is thereby considerably shortened. Although his series is a rather small one from which to make deductions, it appears as if there is merit in his method of procedure in selected cases, provided that the débridement is generous enough to remove all affected tissue. I have had no experience with this method. Prompt application of elastic bandages may be necessary to control hemorrhage from arteries too friable to withstand ligature. Emergency amputation of necrotic extremities is rarely necessary, and should be resorted to only if the patient is critically ill from absorption or infection, and only after all other measures have been tried. Indications for amputation may occur within a few hours after the accident, or only after days or weeks. Rarely is primary suture of nerves or tendons necessary.

COMPLICATIONS AND SEQUELAE

In the majority of patients revived from electric shock there are no lasting disturbances. Headache is a common early sequel. Some dilatation of the heart may be present in severe cases. The pulse rate is often slow. There may be inhibition of micturition and marked constipation for many days. In severe cases acute cerebral edema with epileptiform convulsions may appear, and acute pulmonary edema is not uncommon. Paralyses of various types and grades have also been reported.[30] These are often associated with sensory and reflex disturbances, and they may be transient or permanent. Thompson has reported two cases of internal strabismus, one due to contact of the head with 120 volts, and the other to contact of the mouth with 110 volts.

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28. Monteith, S. R., and Clock R. O.: The Treatment of Burns With Normal Horse Serum, J. A. M. A. **92**:1173 (April 16) 1929. Fisher.[27]

29. Wells, D. B.: Treatment of Electrical Burns by Immediate Resection and Skin Graft, Ann. Surg. **90**:1069, 1929.

30. Jellinek, S.: Paralysis of the Radial Nerve and Trophic Disturbances Following an Electrical Burn, J. Indust. Hyg. **3**:112, 1921-1922. Mendel, K.: Unilateral Spinal Paralysis from Electrical Injury, ibid. **10**:78, 1928.

At various times reports have been made of the association of cutaneous burns with acute gastro-intestinal ulceration in man. In recent experiments on rats [31] high frequency electric burns were associated quite regularly with ulceration of the gastro-intestinal tract. There were no cases of the so-called "Curling" ulcer in my series. Some of the patients showed gastro-intestinal symptoms of a mild type, which cleared up promptly under the administration of sedatives.

Certain sequelae appear quite late, even in cases in which the shock is more or less slight. Of special interest is the effect of the current on the skeletal system.[32] Jellinek has called attention to certain unusually fine and delicate lines in the roentgenogram, some only 1 mm. long, and difficult to distinguish from the normal bone structure. These lines may not appear for two or three weeks, and may arrange themselves in linear, zigzag or stellate patterns. They constitute the mildest manifestation of the effect of the electricity on living bone. Nothing may happen for weeks or months, and finally an osteoporosis may develop to an extent that spontaneous fractures are produced or sequestrums extruded. Areas of rarefaction in the roentgenogram have been traced back to these early manifestations, which occur most commonly at the contact zones.

Other late sequelae may involve the central nervous system. There may be marked disturbances of the psyche, with feelings of inferiority and impending disaster, insomnia, amnesia, defects in concentration, loss of sexual power and psychoneurotic syndromes such as are seen after cerebral concussion. A great variety of sensory and motor disturbances of the nervous system have been reported, e. g., ascending peripheral neuritis, flaccid paralysis of the extremities, peripheral neuritis of the sensory nerves and choreo-athetosic disturbances. The electric flash may be the cause of photophobia, conjunctivitis, retinitis, disturbances in color vision and even atrophy of the optic nerve. Cataract is an occasional sequel to the electric flash, and the possibility of the development of this condition must be considered for a period of two years after the injury.[17] There may be disturbances in blood pressure owing to the effect of the current on the vasomotor center.[33]

When a worker receives a shock from which he recovers within a few minutes, it is the custom of employers to allow him to continue

31. Baldwin, W. M., and Dondate, M.: High Frequency Burns in Rats, Proc. Soc. Exper. Biol. & Med. **27**:65, 1929; Baldwin, W. M., and Nelson, W. C.: Histological Effects Produced in Albino Rats by High Frequency Currents, ibid. **26**:589, 1929.

32. Jellinek, S.: Rontgenologische Knochenaufnahmen bei Behandlung electrische Unfalle, Wien. med. Wchnschr. **79**:543, 1929. Pulugyay, J.: Bone Changes After Injury by Electric Current, J. Indust. Hyg. **7**:180, 1925.

33. Pfalz, W.: Hypertension After Electrical Injury, J. Indust. Hyg. **5**:67, 1923.

with his activities. The complications and sequelae noted should be sufficient warning, however, that every case of electric shock, if at all severe, should be considered as a hospital emergency for several days or until all danger is passed. Victims who have been rendered unconscious, or who have displayed even mild signs of damage to the central nervous system, should be kept at rest for three weeks. Roentgenologic studies of areas which have served as contact poles should be made at regular intervals until all danger of osteoporosis is over.

The victim may be incapacitated for long periods of time as the result of his injury. Especially when psychic disturbances are concerned, one is tempted to brand such patients as malingerers or hysteroneurotic persons. It is often difficult to judge just how much is due to the effect of the current on the body and how much to an attempt on the part of the patient to obtain prolonged compensation. The current is an agent which may produce profound functional changes in the central nervous system, and thus offer difficulty in properly evaluating symptoms which might be ascribed to it.

SUMMARY AND CONCLUSIONS

1. The factors which influence the effect of the electric current on the living organism have been considered.

2. The mechanism of the production of death from electricity in man and in animals has been considered and cases have been cited.

3. It is probable that death from electricity in higher animals is due, in a majority of cases, to primary fibrillation of the ventricles. In man this condition is hopeless unless prompt and heroic treatment is instituted.

4. Postmortem findings fail to explain the cause of electric death. Changes in the walls of the vessels are noteworthy. Heat rather than electrolysis is probably responsible for most pathologic changes.

5. The treatment of electrically induced failure of the respiratory center is artificial respiration by the prone pressure method until the victim breathes or until death is certain.

6. The treatment of electrically induced ventricular fibrillation is prompt cardiac massage, preceded if possible by the intraventricular injection of potassium salts followed by calcium salts. The carotid route for the administration of these salts may prove sufficient without the use of cardiac massage. If available, an appropriate current may be passed through the heart, followed by cardiac massage.

7. The value of prolonged artificial respiration as a life-saving measure in unconsciousness produced by the electric current seems to have been overestimated. In 82 per cent of twenty-seven collected cases the patients died despite its use under ideal conditions over long periods of time.

8. Stimulating hypodermics, inhalation of pure oxygen and countershock are not advised. Inhalation of carbogen is a valuable aid to artificial respiration. Lumbar puncture has a definite place in the treatment of certain patients.

9. Electric burns may be treated by radiant and ultraviolet irradiation. Ointments and dusting powders are not advised in severe burns. Immediate débridement and skin graft have been successful in a small number of cases. On the whole, surgery should be employed with caution.

10. The sequelae of electric shock are many and varied. The most important ones affect the skeletal and nervous systems.

CARCINOMA OF THE LIP

CLINICOPATHOLOGIC ANALYSIS OF SEVENTY-SEVEN CASES AND SUGGESTION FOR RATIONAL PLAN OF TREATMENT

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In a recent review of seventy-seven cases of carcinoma of the lip, several interesting facts were revealed and considered worthy of publication.

Epidermoid carcinoma of the lip comprises from 2 to 3 per cent of all cases of cancer and occurs twelve times as frequently on the lower lip as on the upper.[1] The factor of regional metastasis transforms the primary lesion from a relatively innocuous and curable one to an incurable one in at least 50 per cent of the cases. Metastasis to regional nodes (submental and submaxillary) is an embolic phenomenon. As a rule, metastasis from a cancer of the lower lip appears first in the submental glands and then in the ipsolateral submaxillary glands. However, in many instances the first metastases appear in the contralateral submaxillary glands. The regional glands of the neck present an almost impassable barrier to further metastasis. Remote metastases occur in only about 1 per cent of cases. In general, when death results from cancer of the head and neck, it is because of local and regional development of the disease and not because of distant invasion.

The attitude toward treatment of cancer of the lip has been consistently in favor of some form of radical dissection of regional nodes. However, Bloodgood has recently emphasized the fact that early spinal cell cancer of the lip is seldom associated with metastasis, and that if metastasis is present, it is most frequently a late event.[2] He recommends the cell grading of Broders and McCarthy as valuable in determining the treatment of cancer of the lip.

Dr. Edmund Kelly has studied the results in a large series of patients treated at the Kelly Institute in Baltimore, and briefly sums up his impressions as follows[3]: The cases fall roughly into three groups. In the first group, in which the primary lesion does not involve more than one half of the lip and there is no palpable evidence of metastasis

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1. Crile, G. W.: Cancer of the Jaws, Tongue, Cheek and Lips, Surg., Gynec. & Obst. **36**:159 (Feb.) 1923.

2. Bloodgood, J. C.: Cancer of the Lip, in Lewis, Dean: Practice of Surgery, Hagerstown, Md., W. F. Prior Company, 1930, vol. 4, chap. 4, p. 74.

3. Personal communication.

to the glands, more than 95 per cent of complete, permanent cures are obtained with a single treatment with radium. In the second group, in which the primary lesion involves not more than one half of the lip and a few small palpable glands are involved, there are occasionally complete cures and frequently good palliation. In the third group, in which the lesion involves more than one half of the lip or is invading the cheek and is associated with large metastatic glands, no cures are obtained, and palliation is hardly worth while. Dr. Kelly expressed the belief that if small glands are palpable, excision may be advisable. If no glands are palpable, the neck should be spared dissection, since, in his experience, metastasis has almost always occurred late and only after the primary lesion is advanced and secondarily infected.

In general, the cases fall into three groups: Group A consists of those cases in which the patients present epidermoid carcinoma of the lip, with no palpable evidence of glandular metastases. The results of surgical intervention or radium therapy in these cases are uniformly excellent. The reason is obvious and twofold—early attack and accessibility. Which manner of treatment one chooses is essentially of minor consequence. Radium is "easier to take." On the other hand, by surgical excision the lesion is removed at once and the possibility of leaving a few viable cancer cells lurking in the scar is completely obviated. In addition, excision makes it possible to study the primary lesion microscopically, which, as will be referred to later, I believe is of much more than academic importance.

Group B consists of cases in which there are palpable submaxillary or submental glands which have not become so large and tumefied as to be obviously malignant. It is not to be denied that an attempt to differentiate between inflammatory hyperplasia and glands containing tumor cells will be productive of a large percentage of errors.[4] It is for this reason that statistics concerning this group of cases from a radiologic clinic or, in any event, from a place where microscopic sections are not available, are to be strongly questioned. The present study bears this out. That is, a clinical diagnosis of metastasis has proved to be wrong so much more frequently than the reverse error has been made that, in the absence of microscopic proof, results from radium therapy may seem miraculous but are only misleading. It is this group that deserves the most careful attention and discrimination. Our results are in accord with those of Dr. Bloodgood, who stated that much unnecessary surgical intervention is done in these cases.

4. In order to have a more accurate record of these cases for purposes of subsequent study, a pictorial form has been introduced. See figure 1 in connection with case report of G. O. (case 25). Such a diagram might be of value to the surgeon as a record, and in teaching hospitals should represent the composite opinion of all the members of the staff at the time when general rounds are made.

Our records show that altogether too large a proportion of patients have been subjected unnecessarily to a bilateral block dissection of the submaxillary regions, including the submaxillary salivary glands. It might be argued that chances should not be taken. The operative field is a vascular one; healing is good, and no untoward results seem to occur from the loss of both submaxillary salivary glands. If this were true, it would still not meet the endorsement of good surgical

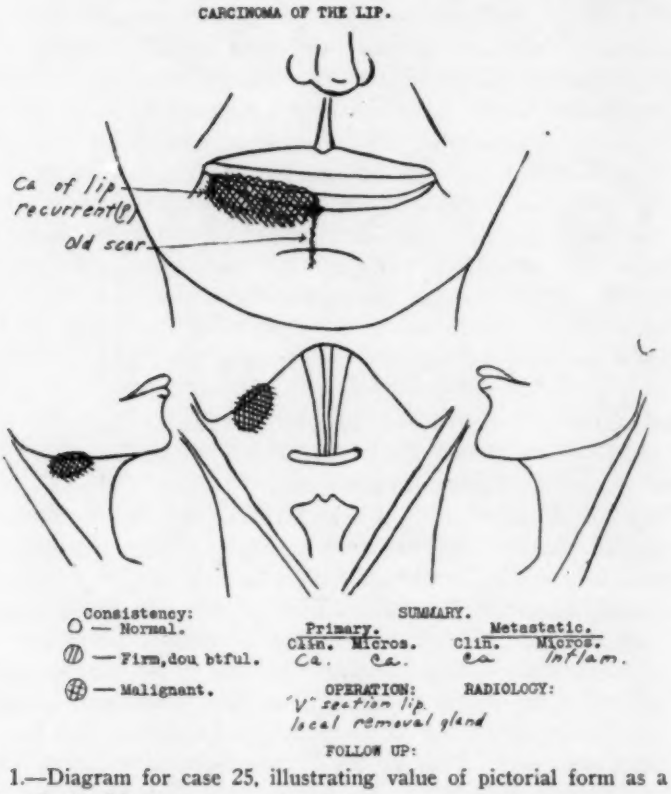

Fig. 1.—Diagram for case 25, illustrating value of pictorial form as a record and its use in teaching.

practice. More careful discrimination leading to the preservation of tissue is a far greater surgical conquest than a presumably good result under an unnecessary scar.

In group C should be included cases of advanced primary lesions and metastases. Though these patients should be given every benefit that surgical intervention and radium therapy can feasibly and practicably offer, there is no doubt concerning the prognosis.

The present analysis of cases has been divided into two parts. In part I, the clinical picture is correlated with the pathologic observations

TABLE 1.—*Correlation Between Histologic Appearance of Primary Lesion and the Clinical Course*

1. *Only "V" Section*

Case	Follow-Up and Comments
1	Well, 5 years*
2	Well, 12 years
3	Well, 6 years; an adenocarcinoma
4	Well, 4 years
5	Well, ? years
6	Well, 5 years; small sore on lip at present
7	Well, 5 years
8	Well, 5 years, "V" section; removed a gland for biopsy, which was negative; excision of recurrence on lip one month later; now well after five years
9	Early recurrence on lip, treated elsewhere
10	Recurrence on lip (4 by 8 cm.) with walnut-sized gland in left submaxilla one year, nine months later; lesion practically inoperable when first seen; plastic repair of lip necessary, and operation palliative
11	No radical operation because of age; returned in five months with painful mass in right submaxillary region; too advanced for benefit
12	"V" section with plastic operation; operation only for palliation; no report
13	No report
14	No report
15	Well, 7 years; died of other cause
16	No report
17	No report
18	Had no palpable glands; no report
19	Well, 8 years
20	Well, 9 years
21	Deep ulcer, no palpable glands; required plastic operation; no report
22	Required plastic operation; no report

2a. *Radical Bilateral Dissection; Clinically, Metastasis; Microscopically, Negative*

Case	Comment	Follow-Up
23	Had small hard submental gland.....	Well 7 years
24	Had small freely movable submaxillary gland.....	Well 9 years
25	Operation, 1921; recurrence (?) ten years later; submaxillary gland removed in 1931; microscopically negative (fig. 1)	
26	.....	Red pimple appears on lip occasionally and goes away; otherwise well three years
27	Bilateral metastasis clinically.....	Well 4 months
28	.....	No report
29	.....	No report
30	.....	No report
31	.....	No report
32	.....	Well 8 years
33	.....	No report
34	Clinical submental carcinoma.....	Well 8 years
35	.....	No report
36	A gland near median line was aberrant thyroid.....	Well 14 years
37	Lip well 11 years; lesion developed on back of tongue destroying one half of tongue and causing aphonia; diagnosed as tuberculosis by home physician	
38	.....	No report

2b. *Radical Bilateral Dissection; Clinically, Metastasis; Microscopically, Positive*

Case	Follow-Up
39	Returned in 2 months (dry mouth), no recurrence; 4 months later, walnut-sized metastasis to left submaxillary; excised; 1 month later, two more metastatic nodules; 2 months later, many cervical nodes involved
40	Well 3 years
41	No recurrence in 16 months; swelling in left lower part of neck 3 years later
42	Recurrence on lip in 2 months and metastasis in right submaxillary region growing fast and painful
43	Well 2.5 years
44	Well 10 years (seen in person; result excellent)
45	Died in 7 months; tumor destroyed lower part of face, tongue and part of upper jaw
46	Died in 2 years of recurrence
47	Died in 2 years from extension in the neck

2c. *Radical Bilateral Dissection; Clinically, Negative; Microscopically, Positive*

Case	Comment	Follow-Up
48	No glands mentioned in the record of this patient, but at operation, a left submental metastatic node found which should have been palpated clinically	8 years later "sore" appeared on the lip, disappeared under home remedies; no recurrence for 3 years

* The follow-up denotes the status to the end of 1930. "Well" means that there is no evidence of any lesion on the lip or palpable lump under the jaws or chin.

TABLE 1.—*Correlation Between Histologic Appearance of Primary Lesion and the Clinical Course—Continued*

2d. *Radical Bilateral Dissection; Clinically, Negative; Microscopically, Negative*

Case	Follow-Up
49	Well, 2 years
50	Well, 2.5 years
51	Well, 2 years
52	Well, 2 years
53	Well, 2 years
54	Well, 2 years
55	Well, 2.5 years
56	Well, 10 years
57	Well, 5 years
58	Died in 15 months of other cause; lip well
59	No report
60	No report
61	Well, 2 years
62	Well, 3 years

3. *Radical Unilateral Dissection*

Case	Comment	Follow-Up
63	Clinically and microscopically negative; right radical dissection	Well 3 years
64	Clinically and microscopically negative	Well until death from other cause
65	Clinically and microscopically negative; left radical dissection	Died in 5 years of other cause; lip well
66	Clinical findings positive for glands on left; microscopically negative	Well 3 years
67	Clinical data positive for submental gland; microscopic data negative	Well 3 years
68	Clinically positive; microscopic data negative	Well 3 years
69	Clinical findings suggestive; microscopic data negative; right radical dissection	Died of other cause in 9 years; lip well
70	Clinical findings suggestive; microscopic data negative; left radical dissection	10 years later small sore developed on left lower lip; stated appearance not like cancer
71	Clinical findings suggestive; microscopic data negative; left radical dissection	Well 15 years
72	Clinical findings suggestive; microscopic data negative; left radical dissection	No report
73	Clinical data suggestive; microscopic observations negative; left radical dissection	Well 12 years
74	Clinical and microscopic data positive	Died in 8 months of recurrence in neck
75	Clinical and microscopic data positive	Recurrence in lip and neck in 10 months
76	Clinical and microscopic data positive; enlarged gland at carotid bifurcation	Well ? years
77	Clinical and microscopic data positive; left radical dissection	No report

on the glands and the subsequent course. In part II, an independent study of the primary lesion is made in an attempt to find a correlation between its histologic features and the course of the disease.

I. CORRELATION OF CLINICAL PICTURE WITH PATHOLOGIC OBSERVATIONS

Analysis of Cases (Table 1).—The following analysis was made of seventy-seven consecutive cases. They were grouped in three categories:

(1) Cases in which only a "V" section was made for the primary condition and in which the patients were spared the radical operation.

There were twenty-two cases. In eleven the patients have remained well for from four to twelve years; one of them presented a primary

adenocarcinoma of the lip; in two cases the condition was too advanced when the patient was first seen for more than palliation to be attempted, and in eight cases there was no report.

(2) Cases in which bilateral radical dissection of the submaxillary nodes, including the submaxillary salivary glands and submental glands, was performed. These naturally fell into four significant groups with regard to regional metastasis:

(*a*) Cases in which a clinical diagnosis of metastasis was made but in which the microscopic observations were negative. There were sixteen cases of this type; nine of the patients were well for from three to fourteen years, and there was no report on seven.

(*b*) Cases in which both the clinical and the microscopic observations were positive. There were nine such cases. Three of the patients are well after two and one-half, three and ten years, and the other six either died of recurrence or have a recurrence at the time of writing.

(*c*) Cases in which the clinical observations were negative and the microscopic ones positive. There was one case of this type. Palpable glands were not mentioned in the record, but at operation a left submental metastatic node was found which should have been palpated clinically. Eight years later a "sore" appeared on the lip. This disappeared after the use of home remedies and has not recurred for three years.

(*d*) Cases in which both the clinical and the microscopic observations are negative. There were fourteen of this type; eleven of the patients are well after from two to ten years; no report has been received from two, and one died in fifteen months of another cause.

(3.). A group in which only a unilateral radical dissection was done. There were fifteen cases, and they fell into subgroups in about the same proportion as those in which a bilateral radical operation was performed.

Comment.—From these cases, little estimation can be made concerning the added value of irradiation. However, in all cases with proved metastases intensive irradiation was employed. In spite of the combined treatment, the mortality from recurrence was greater than 50 per cent.

In studying the microscopic sections, there is no doubt that a biopsy of the glands palpated would have demonstrated metastases when present, thus eliminating the possibility of an oversight. Experience has shown that the fascia or parenchyma of the salivary glands does not exhibit metastatic cancer cells, except in the most obviously advanced lesions.

Illustrative Case.—The following report (table 1, case 25) is of considerable interest with respect to clinical impression.

G. O., an American laborer, white, entered the hospital on March 10, 1931, with a carcinoma (recurrent?) of the lower lip. Ten years previously, a carcinoma of the lip was resected with a simple "V" section, and bilateral radical dissection of the glands was done at this hospital. The wound healed uneventfully. Six years ago the patient noticed that he was snagging his lower lip with a jagged upper incisor. Three months ago a painless ulcer appeared to the right of the old scar.

On examination, a vertical midline scar of the lower lip and a linear scar below each mandible could be seen. An ulcerating, fungating carcinoma occupied practically the entire right half of the lip, including a part of the scar region. The base was indurated. A prominent, firm, fixed gland about 1.5 cm. in diameter was located just below the angle of the right mandible.

It is interesting to speculate on whether the carcinoma was recurrent after such a length of time or whether it was a new and independent lesion. However, there was no doubt that the enlarged gland was involved by metastases. The lesion of the lip was excised with an adequate margin, the closure being aided by a right Dieffenbach plastic procedure, and several days later the gland was removed. The latter was examined carefully microscopically; only inflammatory tissue was revealed.

Factors of Interest.—All cases occurred in patients between the ages of 38 and 80, and the relative proportions in the fifth, sixth, seventh and eighth decades were 9, 26, 23 and 19.

The relation of males to females was 76: 1.

All patients were of the white race.

The duration of the lesion before the patient came to the hospital ranged from three weeks to twenty years. Between these extremes, ordinary averages do not mean a great deal. Curiously enough, however, in the entire group in which there were nonmetastatic lesions, there was an average duration of twice that of the group in which there were metastatic lesions; this fact indicates that neglect of the lesion or its duration is not so important as the type or grade of malignancy.

Etiology.—While it is true that in more than 90 per cent of the instances one can elicit the occasion of irritation and trauma to the lips, no correlation between the irritation and the grade of malignancy is exhibited. In fact, the patient presenting one of the most malignant recurrences seen in group 2 *b* (case 42) did not smoke, and he remembered no trauma other than the initial lesion. While I believe that irritation and trauma conducive to a long-continued inflammation are most important factors in the etiology of cancer, particularly of the skin, they are only factors and ones about which, taken as a whole, little is known. There are, on the one hand, enough patients presenting carcinoma of the lip who do not smoke and, on the other hand, a large enough population of incessant smokers who never have cancer of the lip to make one look on smoking as a specific cause with considerable reservation.

Summary.—1. Eighty per cent of epidermoid carcinomas of the lip are essentially a benign form of neoplasm and are slow to metastasize. The prognosis after conservative surgical intervention in these cases ranges from good to excellent.

2. Ability to determine metastasis clinically is inadequate.

3. There is a relatively small group of lesions which appear clinically to be highly malignant. Metastases develop early, and regardless of radical surgical intervention plus intensive irradiation, 50 per cent of the patients at best may be cured.

II. PATHOLOGY OF THE PRIMARY LESION AND ITS CORRELATION TO METASTASIS AND PROGNOSIS

Degree of Malignancy.—It is of interest to note whether there is a dependable relation between the histologic appearance of the primary carcinoma of the lip and the clinical progress and ultimate prognosis.

Since the time of Virchow, it has been recognized that the degree of malignancy of a neoplasm is inversely proportional, in a general way, to the degree of differentiation which the type cell undergoes. The degree of differentiation itself is manifested by the histologic features of the tumor. Broders and McCarthy have made commendable efforts toward classifying neoplasms in four categories on this basis, with the view to introduce a rational correlation between the histology of the primary tumor and what may be expected of its natural history.

In exceptional instances the rules laid down will not hold, but in general they apply with as great a percentage of accuracy as in the interpretation of any complex biologic phenomenon.

In brief, Broders and McCarthy have placed the neoplasms in which the type cell is undergoing the most advanced differentiation (and which therefore are least malignant) in group 1 and those showing the least evidence of differentiation (and which therefore are the most malignant) in group 4. The remainder of the neoplasms they have placed in the intermediate groups, 2 and 3.

In the application of these principles to carcinoma of the lip, keratinization and pearls, in general, give evidence of the advanced differentiation of the epithelial cell, and signify, as a rule, a carcinoma of relatively low malignancy. Other factors must be taken into consideration, but there seems to be no doubt that an epidermoid carcinoma composed of large papilliform groups of cells in fairly regular formation and undergoing complete differentiation to form large, keratinized pearls is a relatively slow-growing tumor with little propensity for early metastasis. Indeed, many of the large keratinized pearls surrounded by a layer of epithelial cells differentiating from a fairly well

defined basal cell to the ultimate corneum appear not unlike tiny epithelial inclusion cysts. Again, such masses of buried epithelium evoke a considerable foreign body reaction and one often sees, in places, many foreign body giant cells, a thick barrier of leukocytic cells and, further, an attempt to check the progress of the lesion with a wall of scar tissue.

On the other hand, when the cells are present in undifferentiated masses or cords and show abundant mitotic figures, as these types most often do, the grade of malignancy is high, with a tendency toward early metastasis. Therefore, there is no question but that a study of the primary lesion can be of considerable value in augmenting the knowledge one has gained from the clinical study.

Broders' Classification.—Broders, in 1920, made an extensive survey of 537 cases of carcinoma of the lip.[5] The following is a brief summary of some of the information.

Pathologic observations in cases in which nodes were removed (449 cases):

(a) No metastases found 344 (76.62%)
Metastases found 105 (23.38%)

(b) Degree of malignancy:

Grade	Per Cent
1.	15.82
2.	62.01
3.	21.04
4.	1.11

(c) Average size of ulcer:

Grade	Cm.
1.	1.23
2.	2.28
3.	3.25
4.	1.90

	With Metastasis	Without Metastasis
(d) Average size of ulcer	3.74 cm.	2.01 cm.
Average duration	3.27 yrs.	2.40 yrs.

Therefore (*c*) and (*d*) show that the size of the ulcer is no indication of its degree of malignancy. One is not justified in determining the lesion from its gross appearance. The size and duration of the primary lesion are not, within reasonable limits, indications of the presence or absence of metastases.

5. Broders, A. C.: Squamous Cell Epithelioma of the Lip: A Study of Five Hundred and Thirty-Seven Cases, J. A. M. A. **74**:656 (March 6) 1920.

(e) Relation of degree of malignancy to metastasis:

Cases	Grade of Malignancy	Metastasis	No Metastasis
67	1	0	67 (100%)
287	2	39	248
92	3	63	29
3	4	3 (100%)	0

Therefore 79 per cent of the cases fall in groups 1 and 2 and 21 per cent in 3 and 4.

In groups 1 and 2 combined, 11 per cent of the cases show metastasis, and 89 per cent are without metastasis.

In groups 3 and 4 combined, 66 per cent of the cases show metastasis, and 34 per cent are without metastasis.

It would seem, then, that there is ample room for discrimination in dealing with carcinoma of the lip, and that some more rational working plan could and should be established for its treatment.

Author's Classification.—My associates and I do not follow Broders' classification exactly, but feel that an adequate working plan can be formulated as follows, and it is on this basis that our primary lesions have been classified:

Group 1, the very benign appearing lesions, including warts, so-called precancerous lesions and epidermoid carcinomas, which would fall in Broders' grade 1 (fig. 2).

Group 2, epidermoid carcinomas which show an advanced degree of differentiation, with more extensive keratinization and pearl formation than in group 1 (fig. 3).

Group 3, a group corresponding to Broders' grade 4, that of the obviously malignant lesion as evidenced by lack of differentiation and the abundance of mitotic figures. An occasional lesion will show keratinization and yet will be placed in this group, for example, one in which keratinization is evident but small in amount or one in which the cells are greatly scattered and dissociated, with multiple tiny pearls. The mere presence of a pearl here and there does not necessarily militate against the lesion's being highly malignant. After all, there are no sharp lines of separation (fig. 4).

The microscopic sections of the primary lesions in the following cases were studied and classified without knowledge as to which cases they belonged. The case numbers were later attached. Sections for all of the cases were unfortunately not available. Sections from cases in which the condition was inoperable when the patient was first seen were not included for obvious reasons. Any malignant lesion if neglected and given time enough will become inoperable, owing to either size or metastasis and, as stated early in the paper, attention is not directed to the cases in which the condition is obviously inoperable

Fig. 2.—Low power photomicrographs of epidermoid carcinomas of the lip which are considered typical of group 1 (table 2).

when first seen. As a corollary to this, occasionally a primary lesion is removed which, though exhibiting the characteristics of high grade malignancy, is not accompanied by metastasis, and a cure will be effected.[6]

Analysis of Cases (Table 2).—Sixteen cases fell in group 1. Naturally, all of these lesions showed marked keratinization and well defined limitation. When these were correlated with the respective cases, it was found that a radical dissection of the glands had been performed in twelve. None of these revealed metastases. Ten patients were reported as being well from two to fourteen years afterward.

Twenty cases fell in group 2. All of the lesions showed marked keratinization also, but were not so markedly delimited as in group 1, and

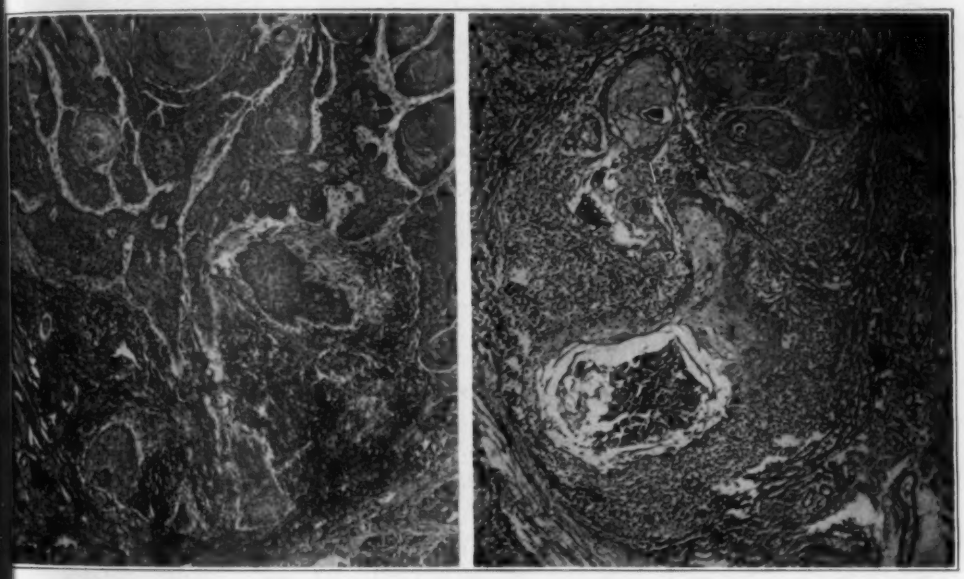

Fig. 3.—Low power photomicrographs of epidermoid carcinomas of the lip which are considered typical of group 2 (table 2).

were more advanced. Twelve patients had undergone the radical operation. Only two of them revealed metastases; in one, the process was fatal, and the other patient has been well for two and one-half years. In eight cases, radical operation was not performed, but five of the patients were reported as being well from five to nine years later.

Ten cases fell in group 3. Seven of the patients had undergone the radical operation; in six instances metastases were revealed. Four of the six patients died with recurrence; one is alive after three years, and the other did not report.

6. Dr. Schenken of the Department of Pathology aided me in the study of the primary lesions.

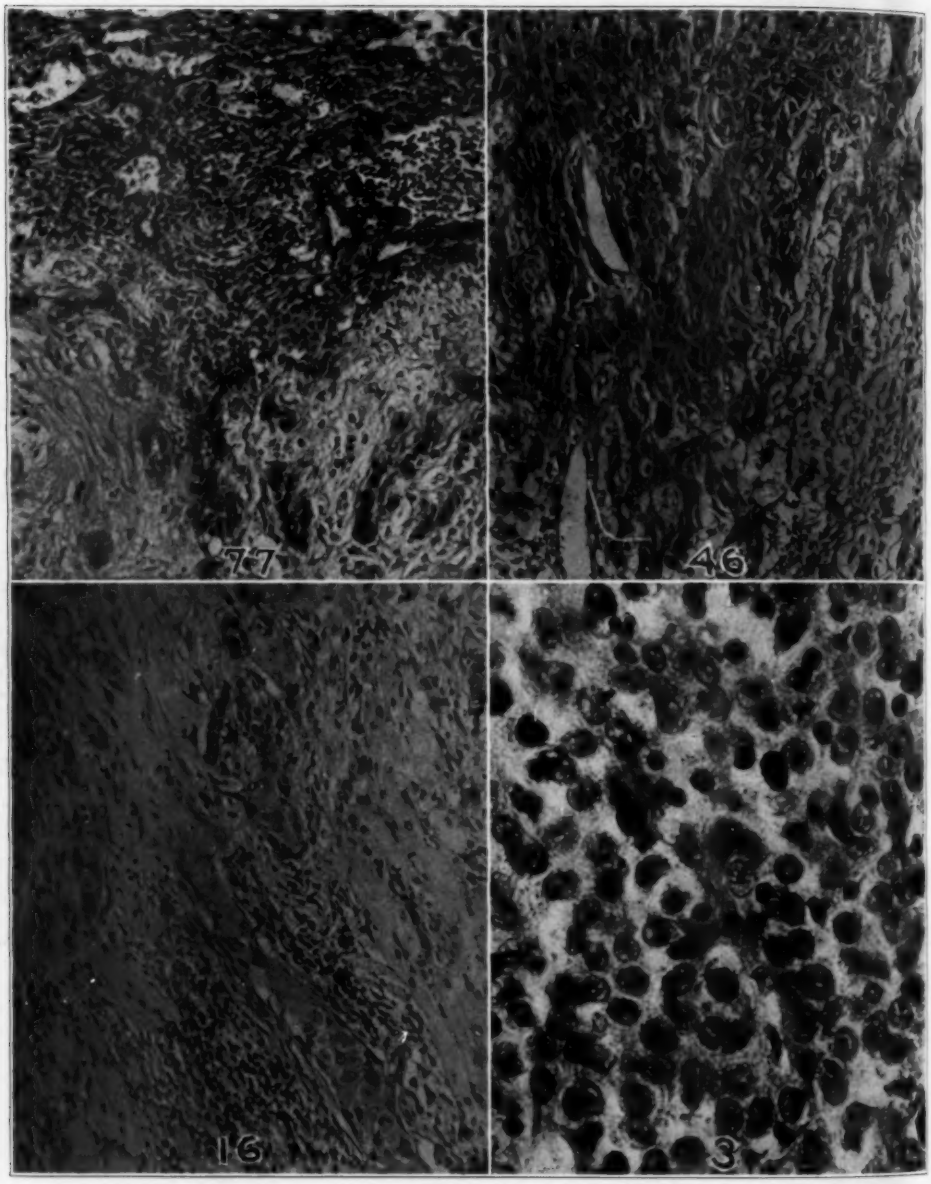

Fig. 4.—High power photomicrographs of epidermoid carcinomas of the lip that are considered typical of group 3 (table 2). These are characterized by little or no keratinization, infiltration and abundant mitotic figures. The photomicrograph from case 3 is an adenocarcinoma of the lower lip, which may well have arisen from a salivary rest, a rare but not unknown carcinoma of the lip.[1] It is included in this group as it should obviously be treated as a highly malignant tumor. Note the many mitotic figures. The primary lesion only was removed in this case, and the patient is well after six years. In the photomicrograph from case 16, a lymph channel is seen filled with cancer cells.

All lesions in this group revealed an undifferentiated cell with infiltration and no keratinization, except one, in which the cells were greatly scattered, and in which there were multiple tiny pearls.

In case 3 the process proved to be a primary adenocarcinoma which appeared highly malignant intrinsically, but which seemed well encapsulated; it was excised with a wide margin. This case is included with the epidermoid carcinomas because when such a process is found it should be obviously treated as a group 3 lesion (case 3, fig. 4).

In summary, therefore, thirty-six of the primary lesions were classed histologically as relatively benign. Only two of them were associated with metastases at the time a radical operation was done. Only a small

TABLE 2.—*Arrangement of Cases According to the Histologic Appearance of the Primary Lesions*

Group 1	Group 2	Group 3
4:K:V:4*	6:K:V:5	16:K:V:—
9:K:V:?	7:K:V:5	3:—:V:6; adenocarcinoma
13:K:V:—	8:K:V:5	54:—:R:N:2
17:K:V:—	14:K:V:—	40:—:R:M:3
23:K:R:N:7	49:K:R:N:2	42:—:R:M: rapid recurrence
26:K:R:N:3	51:K:R:N:2	45:—:R:M: died of recurrence 7 mos.
27:K:R:N:4 mos.	58:K:R:N:—	46:—:R:M: died of recurrence 2 yrs.
28:K:R:N:—	61:K:R:N:2	74:—:R:M: died of recurrence 8 mos.
29:K:R:N:—	67:K:R:N:—	77:—:R:M:—
52:K:R:N:2	18:K:V:—	22:—:VP:—
57:K:R:N:5	34:K:R:N:8	
62:K:R:N:3	19:K:V:8	
63:K:R:N:3	20:K:V:9	
68:K:R:N:3	35:K:R:N:—	
72:K:R:N:—	37:K:R:N:11	
36:K:R:N:14 (aberrant thyroid)	32:K:R:N:8	
	21:K:VP:—	
	31:K:R:N:—	
	39:K:R: microscopic metastasis recurred in many nodes	
	43:K:R: microscopic metastasis, well 2.5 yrs.	

* Left hand numeral indicates case number; K, keratinization; V, received only "V" section; VP, only "V" section, but required plastic repair; R, some form of radical section; N, no microscopic metastases, and M, demonstrated metastases. The last numeral indicates the number of years the patient has been free from recurrence; and —, no report from follow-up.

percentage remain uproved as to metastasis, that is, the few patients on whom a radical operation was not performed and from whom a follow-up report was not received. On the other hand, of the ten lesions which were classed as highly malignant histologically, six showed metastases, and more than half ended fatally.

So far as a working knowledge is concerned, one might classify groups 1 and 2 as a single group, except that it is perhaps well to provide a group to accommodate lesions the malignancy of which is questionable. In studying the sections of the primary lesions the impression was gained that the nonkeratinizing ones which fell in the highly malignant class arose from the buccal side of the lip. It seems rather logical that this is true. The usual keratinizing carcinoma of the lip should be comparable to other epidermoid carcinomas of the skin. In general,

the latter are slow-growing, and they metastasize late. On the other hand, carcinomas of the buccal mucous membrane present keratinization less frequently and have a greater propensity for early metastasis as well as for rapid growth.

The results of this review bear out the fact that a rational working plan can be obtained concerning the treatment of carcinoma of the lip with respect to the advisability of a block dissection of the glands of the neck and irradiation. The criteria for formulating judgment as to the method of treatment are: (1) careful clinical examination and (2) microscopic study of the primary lesion. A plan such as the following one may be followed:

(*a*) If no submaxillary or submental glands are palpable, remove by adequate margin the primary lesion. If the microscopic study proves the lesion to be in groups 1 or 2 as previously mentioned, further surgical intervention would not be advised.

(*b*) If submaxillary or submental glands are palpable and their condition is questionable, one or more of those most suspected may be easily removed under local anesthesia and examined by the pathologist. Frozen section, if available, may be of considerable aid and expedite further surgical procedures if they are indicated. If the sections do not show metastases, remove the primary lesion only. If microscopic study of the primary lesion proves it to be in groups 1 and 2, further surgical intervention would not be advised. (The glands which were removed may also be studied in the routine manner.) If a metastatic lesion is found in any gland, a thorough bilateral block dissection of at least the submaxillary and submental glands followed by an adequate course of irradiation should be done. (Whether or not block dissection of the anterior cervical nodes should be carried out in such an instance is a matter of personal opinion.)

(*c*) If the primary lesion falls in group 3, its high grade of malignancy and propensity for early metastasis indicate complete block dissection followed by irradiation, regardless of the clinical findings. If in any instance a patient should be given radical surgical treatment and irradiation, regardless of the clinical findings, it is the patient whose lesion is classified in this group.

It will be observed that irradiation is not advised unless there is surgical intervention. If apparently block dissection of the glands is not indicated, then, to be consistent, irradiation is not indicated. On the other hand, if a metastatic lesion is found, or if the primary lesion falls in group 3, I believe that one should employ both radical surgical treatment and adequate irradiation. When one is dealing with the glands, irradiation is at best only an adjunct to surgical intervention. As a corollary to this statement, I do not feel that unilateral block

dissection of the glands of the neck is ever indicated for carcinoma of the lip. Instances of crossed metastases are too common to make such a procedure adequate.

If the case falls in classification *a*, irradiation alone of the primary lesion may be an alternative procedure, with satisfactory results, but this would deprive one of a study of the lesion, which I feel is of considerably more than academic importance.

Comment.—In consideration of the patient's expense for hospitalization, as well as of the problem in charity and in state hospitals where beds are always at a high premium, the question of whether or not a patient should be kept for postoperative irradiation is a constant source of anguish to the surgeon. He often entertains a strong doubt as to either the necessity for or the benefit which may be derived from a course of irradiation in many cases, and yet he wishes to give the patient every benefit that can be had. I feel that this study offers a plan which will dispense with many irregularities. Since block dissection of the glands and irradiation are indicated in a relatively small percentage of cases of carcinoma of the lip, the time of hospitalization for all the patients will be minimum, and yet all the treatment that is indicated will be given. The large group will be spared an unnecessary block dissection of the neck and the small group in which it is indicated will be given the maximum benefit of radical surgical treatment and irradiation.

CONCLUSIONS

1. About 80 per cent of epidermoid carcinomas involving not more than one half of the lower lip will not be associated with regional metastases. The indiscriminate use of radical surgical intervention and irradiation is neither necessary nor to the best interest of these patients.

2. A small percentage of carcinomas of the lip are nonkeratinizing and metastasize early. In these cases there are not more than 50 per cent of cures. It is the impression that these lesions arise from the buccal mucous membrane and bear the characteristics of buccal carcinomas elsewhere, while the relatively benign, keratinizing cancer of the lip bears the characteristics of epidermoid carcinomas of the skin in general.

3. One is not licensed to say that epidermoid carcinoma metastasizes early or late without giving consideration to the degree of malignancy in each case.

4. Since for the great majority of patients having carcinoma of the lower lip radical dissection of the glands will be found not to be indicated, these patients should be spared radical operation. On the other hand, when metastasis is proved or when the primary lesion is histo-

logically highly malignant, complete bilateral dissection of the regional glands followed by irradiation should be done.

5. Histologic study of the primary carcinoma is valuable in determining the likelihood of early metastasis.

6. A rational plan for the management of carcinoma of the lip is suggested.

AMPUTATION THROUGH LOWER THIRD OF LEG FOR DIABETIC AND ARTERIOSCLEROTIC GANGRENE

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Frederic S. Dennis,[1] professor of surgery in Bellevue Hospital Medical School, in 1887, during a clinical lecture on the general principles involved in amputation, quoted the late Sir William Fergussen as saying, "Amputation is one of the meanest and yet one of the greatest operations in surgery"—"mean" when resorted to if better may be done and "great" if the only step to give comfort and prolong life.

Probably the earliest amputations done on man precede all available records. However, it is recorded that Hippocrates, 400 years before the Christian era, practiced amputation of gangrenous legs by cutting through the upper portion of the area of gangrene with a chisel and mallet or shears, not entering the sound tissue above the area.

This practice continued until the reign of Augustus Caesar at about the beginning of the Christian era, at which time Celsus was the first to practice circular no flap amputation with a scalpel through sound tissues above the area of gangrene. This technic of Celsus was followed for approximately 1,700 years, until the time of Lowdham of England, who is the first recorded to advocate flap amputations. Alanson,[2] surgeon to the Liverpool Infirmary, published in book form, in 1782, observations of his own and his confreres on the flap method. It was not, however, until the first half of the nineteenth century that flap amputations were universally recognized and practiced. Credit for the advance and improvement of this technic is due to such men as Langenbeck, Lister, Teale, Syme, Lisfranc and Chopart. In 1886, Dennis [1] published his observations on the treatment of amputation by the open method at Bellevue Hospital. He records fourteen consecutive amputations without deaths, performed by Dr. James R. Wood, in which the stumps were left entirely open, as a remarkable surgical achievement at that time.

Read before the Surgical Section, New York Academy of Medicine, Jan. 8, 1932.

1. Dennis, F. S.: Clinical Lecture on the General Principles Involved in Amputation, J. A. M. A. **18**:505 (May 7) 1887.

2. Alanson, E.: Practical Observations on Amputations and the After-Treatment, ed. 2, London, J. Johnson, 1782, p. 8.

Since the discovery of insulin in 1921, and the subsequent study of diabetes and coincident gangrene, amputations in septic diabetes have frequently reverted to the type of operation done by Celsus at the beginning of the Christian era, subsequently known as the guillotine. The so-called guillotine amputation, however, received its name from the technic of Leonard Botalli,[3] surgeon to Charles IX, King of France in the sixteenth century, who first devised and used the guillotine for amputating extremities, sealing the bleeding vessels, immediately after the falling knife had severed the member, with heated irons or oils.

Recent studies of vascular diseases of extremities have brought new problems in amputations, and the development of the technic here reported is an outgrowth of observations during the past two years on patients in the surgical diabetic service of the Presbyterian Hospital.

It is with timidity that I report the following technic as original. The literature on amputations is so extensive that I have not been able to cover it completely, but that which I have reviewed has not produced reference to this type of amputation applied to this group of vascular diseases.

Persons with arteriosclerosis and diabetes constitute a group particularly susceptible to infections and gangrene of their lower extremities. The mortality from amputations in this group is still high in spite of its reduction in various clinics since the introduction of insulin which has permitted more conservative as well as more radical surgical procedures.

The type and site of amputation in cases of arteriosclerotic diabetes demand considerations of the social and economic status of the patient, besides principles of wound healing, routes of infection and the adequacy of the peripheral and collateral circulation. Most persons with diabetes with infected extremities show evidence of advanced general and peripheral sclerosis. Patients with arteriosclerosis and diabetes constitute by far the largest number seen in clinics with infection and gangrene of their lower extremities. The next largest group is composed of those with arteriosclerosis without diabetes and the smallest group of those with diabetes with infection without sclerosis.

The surgical work of Dr. D. F. Jones and Dr. L. McKittrick in conjunction with the medical work of Dr. E. Joslin at the Deaconess Hospital in Boston has recently stimulated the study of surgery in diabetic patients. They have emphasized to the great benefit of septic patients with diabetes and gangrene the efficacy of a guillotine amputation through the lower third of the leg. The immediate effect of this procedure on the condition of sepsis is salutary, if no other septic foci have developed because it separates the patient from the origin of

3. Watson, B. A.: Amputations and Their Complications, Philadelphia, Blakiston's Son & Co., 1885, p. 16.

his infection. They have followed a guillotine amputation, which is a life-saving measure in many cases, by some type of plastic operation on the stump or by higher amputation.

Experience with septic diabetes with gangrene and the success of the guillotine amputation in preventing the continuation or spread of sepsis have established the procedure in the diabetic surgical armamentarium as effective and often dramatic.

Following a guillotine amputation, stumps frequently present the following problem:

1. Slow healing requiring hospitalization for from two to four months, if the patients remain until the wound heals.

To hurry wound healing, Thiersch grafts have been applied to the end of the stump immediately after the amputation. The grafts are maintained in place by soft sea sponges held against them with flamed sterile adhesive strips. These grafts have been observed to "take" on the soft parts, causing earlier complete epithelization. The grafts have been seen in a few cases to "take" over the marrow of the tibia, but in my cases they have not "taken" over the exposed rim of the tibial cortex.

2. Osteomyelitis with sequestration of a portion of the tibia or fibula, usually the tibia.

Retraction of the soft part in spite of adhesive straps attached to the skin with 2 or 3 pound traction cause the tibial end almost as a rule to present at, or distal to, the soft parts. The sequestration of this bone usually requires forty-five days or longer, and healing of the wound is not complete until after sequestration has occurred. This period of healing has been shortened by ronguering off the tibia during the second or third week after the guillotin amputation. This requires no anesthesia.

3. Attachment of the skin to the tibial stump causing pain, and, when an artificial leg is fitted, often ulceration requiring reamputation.

Observations of stumps produced by guillotine amputation, when fitted to artificial legs, the weight being borne by a laced cuff about the thigh and a socket fitting under the tibial condyle and fibular head, have shown that as the stump sinks into the socket, in spite of there being no pressure or weight-bearing on the end, there is a stretching with consequent blanching of the thin epidermal covering of the stump, which in part decreases its blood supply and permits slight trauma to cause ulceration in the scar.

Reamputation after the guillotine procedure prolongs hospitalization and adds physical and mental strain to already debilitated patients with diabetes. Reamputation higher through the leg involves a decided risk of infection in the stump, sepsis and still further, an amputation through the thigh.

Subsequent Gritti-Stokes amputations deprive the patient of his knee joint. A man who does manual labor may be provided with the most useful type of stump, but this has not seemed to have been true of the more sedentary housewife.

An amputation through the thigh, in spite of its success in other clinics, has seemed to the surgical group at the Presbyterian Hospital often more radical than necessary.

Patients with diabetes and sclerosis with compromised myocardium and peripheral vessel walls, decreased kidney function and innumerable other pathologic signs encountered with an early senility do not stand multiple or repeated surgical procedures well. Death has come so frequently, quickly and unexpectedly, and so often has remained unexplained even by autopsy, that in spite of satisfactory clinical records of cardiorenal vascular competency, I feel a guarded prognosis is necessary in all of these cases.

With the foregoing facts in mind, a type of amputation embodying the following principles was sought:

1. The least possible interference with collateral circulation.
2. More rapid healing of the wound.
3. Guillotine amputation of the soft parts at a right angle.
4. A sufficiently well nourished soft part covering of the ends of the bones.
5. Preservation of the knee joint.
6. The least possible shock.

The following technic of amputation through the lower third of the leg which has proved its usefulness in cases of diabetes and arteriosclerosis in the surgical diabetic clinic at the Presbyterian Hospital is herewith presented.

OPERATIVE TECHNIC

No tourniquet is used except the assistant's encircling hands. After proper preparation of the skin and draping, an incision is begun from 6 to 7 inches (15.2 to 17.8 cm.) below the tibial tubercle over the medial margin of the anteromedial surface of the tibia, at least 3 cm. medial to the tibial crest, deepened through the skin to the periosteum and extended distally from 4 to 5 inches (10.2 to 12.7 cm.) to the point at which the soft parts will be guillotined (fig. 1).

With a curved periosteal elevator, the medial, posterior and lateral group of muscles are separated from the tibia, outside its periosteum. The curved elevator or a flat flexible retractor is left in place posterior to the tibia (fig. 2).

The tibia is severed from 6 to 7 inches below the tubercle, at the upper end of the skin incision, with a Gigli saw or flat chisel. With the latter, there is added danger of injury to the muscles and vessels. The sclerotic tibia may be difficult to sever with a Gigli saw alone. The severed tibia is forcefully drawn forward and medially out of the wound with a hook or rake retractor (figs. 3, 4 and 5).

To sever the fibula, the extensor group of muscles lateral to the tibia is retracted laterally, exposing the fibula. It is easier technically to expose it about 2 cm. below the level at which the tibia has been severed. The

muscles which take origin from the medial surface of the fibula, namely, the extensor hallucis longus, the extensor digitorum longus and the peroneus tertius, are separated for a short distance from the fibula at this point, and the bone is palpated and severed with bone forceps (fig. 5). Care must be taken lest the ends of the bone forceps extend beyond the fibula laterally or posteriorly and damage the peroneal vessels which lie posterolateral to the shaft of the fibula.

Fig. 1.—The skin is incised down to the periosteum on the anteromedial surface of the tibia from 6 inches below the anterior tibial tubercle to the site chosen for amputation of the soft parts.

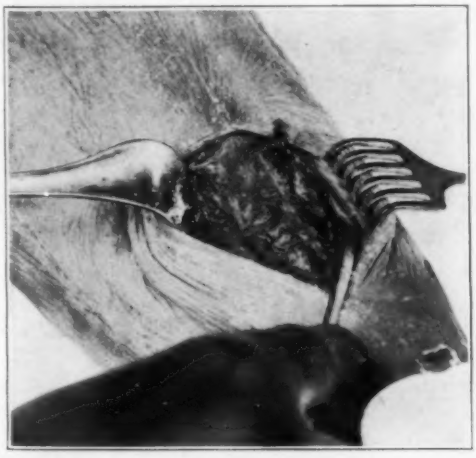

Fig. 2.—The tibialis anterior, the extensor digitorun longus, flexor digitorum communis longus and tibialis posterior muscles were separated from the periosteum of the tibia with a curved periosteal elevator.

Both bones in the part to be amputated are then brought forward out of the wound by depressing the foot (figs. 6 and 7).

This enables the operator to see the muscular attachments which have been severed from the tibia and those to be separated from the fibula downward to the point at which the soft parts are to be guillotined. The muscles can easily be separated from the tibia with a periosteal elevator, but from the fibula the peroneus tertius is best separated by curved scissors (fig. 7).

Once the tibia and fibula have been brought forward out of the wound and separated from their investing muscles, an amputation knife is placed posterior to the bones from 4 to 5 inches below the site of their severance, and the soft parts are guillotined at right angles (fig. 8).

It is important that the guillotine incision through the soft part be at a right angle as this destroys fewer collateral vessels than an oblique incision.

The muscles are then separated from the fibula stump which is still longer than the tibia, and it is reamputated with its periosteum from 1 to 2 cm. above the end of the tibia with a bone forceps (figs. 9 and 10). The tibial crest is beveled through its cortex down to, but not into, the medullary cavity. This minimizes skin injury and bone bleeding and prevents the formation of a subcutaneous hematoma at this point. After the vessels are clamped they are ligated without mass ligatures. The posterior tibial nerve is pulled down for 2 or 3 inches (5 to 7.6 cm.)

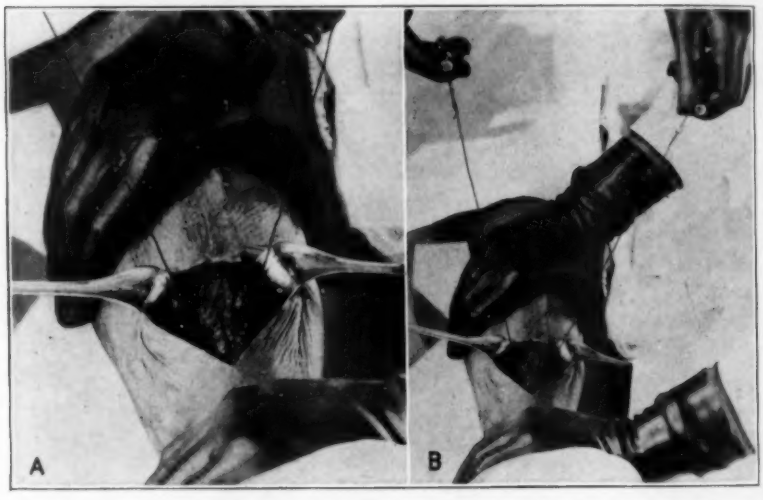

Fig. 3.—*A*, the Gigli saw is in place posterior to the tibia at the upper angle of the wound for division of the tibia. The soft parts are retracted and protected by medium abdominal retractors. *B*, the tibia is being cut across.

and 1 cc. of 1 per cent procaine hydrochloride followed by 1 cc. of 80 per cent alcohol is injected into it; the nerve is severed and allowed to retract.

Closure has been done as follows (fig. 11):

1. Careful hemostasis is employed.

2. In some but not in all cases, the deep fascia is sutured with plain interrupted catgut on a small curved needle, care being taken to approximate the edges exactly.

3. Interrupted silk sutures are used in the skin.

In cases in which drainage is employed skin closure does not approximate the drain too closely.

The soft parts are sutured, drained or left open, depending on the extent of the infection in the foot and tissues through which the amputation is done. When amputation is done for gangrene or infection, the end of the stump is considered a contaminated, potentially infected wound because the lymphatic channels have been divided.

I have employed drainage in all cases in which this method was used to date, a small soft rubber tube or rubber dam being placed down to the space just posterior to the end of the tibia.

Drainage has been used as an added safety factor. The extent and time of drainage have gradually been decreased with added experience in these cases, and although the ultimate aim is for a minimum, I doubt the advisability of closing the stump as a routine procedure without some form of drainage.

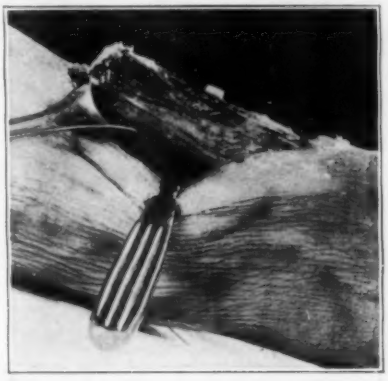

Fig. 4.—The tibia has been cut across and the flexor digitorum communis longus and interosseous membrane have been stripped away from it outside the periosteum with a curved elevator.

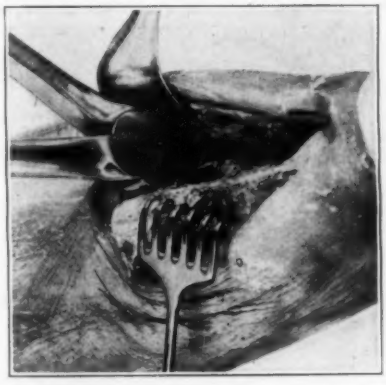

Fig. 5.—The severed lower portion of the tibia is retracted medially. The fibula has been exposed along the interosseous membrane, care being taken to avoid the anterotibial vessels anteriorly, and the peroneal vessels posteriorly near the fibula. The fibula is severed by bone forceps about 2 cm. below the tibia. It is reamputated higher than the tibia later (fig. 9). Exposure of the fibula is technically the most difficult part of this amputation.

Where the limb has been severed through cellulitis and thrombophlebitis, the wound has been left wide open with a small tampon type of a drain of China silk with one or two 1 inch (1.27 cm.) strips of gauze inside the silk. This type of wound is usually converted into an open dressing from about the fourth or fifth

day on. In the partially sutured drained wounds, the tube or rubber dam is usually withdrawn the second day and not replaced unless deemed advisable from the clinical course.

The operator should decide the length of soft parts desired over the ends of the bones. I have found a soft part pad of from 3½ to 5 inches (8.9 to 12.7 cm.) immediately after amputation to have shrunk to one of from 2 to 3 inches six months later. This has been satisfactory to the patient and also to the makers of

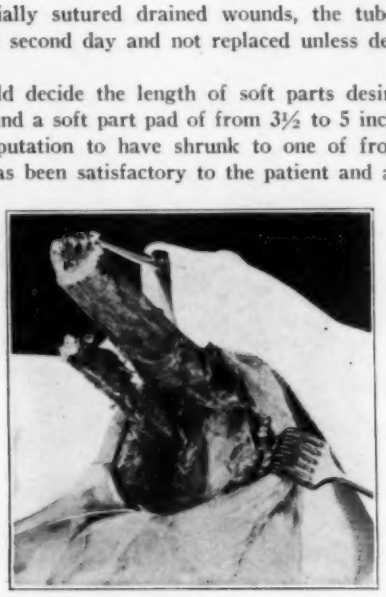

Fig. 6.—The severed fibula and tibial ends are brought out of the wound by depressing the foot, and the muscle groups have been separated from the periosteum of the two bones down to the site at which the soft parts will be amputated.

Fig. 7.—Lateral view of figure 6.

artificial legs, because the end of the stump does not extend too far into the socket to require its lower end being wider than the opposite leg at a corresponding level. This is of cosmetic value to the patient and has avoided the difficulty encountered by manufacturers of prosthesis with the long stumps following guillotine amputations through the lower third of the leg.

With this procedure the necessary subsequent plastic operation is done at the time of amputation. Whereas there is more trauma to the tissue than with the

guillotine amputation, there is, however, less than with flap amputations. To sever the tibia between 6 and 7 inches below its tubercle and leave only a small portion of soft parts covering the bones would necessitate amputation through the lower muscle bellies in the middle third rather than through the tendons in the lower third. Fewer tissue spaces are opened and less collateral circulation disturbed by amputation through tendons than through muscle bellies. This obviously promotes better healing and tends to obviate infection. If tendons interfere with closure of the wound, they are excised near their juncture with the muscle bellies.

Fig. 8.—The amputation knife in position at right angle to the soft parts, severing them in the lower third of the leg from 3 to 4 inches below the site of the bone amputation.

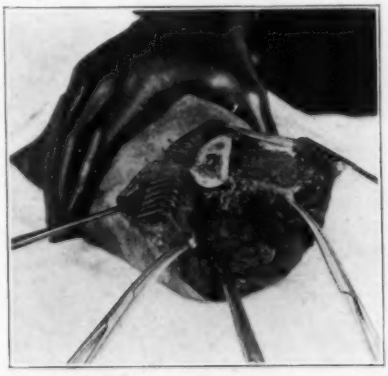

Fig. 9.—End of the amputated stump. The hand was used as a tourniquet. Clamps were placed on the anterior and posterior tibial vessels and posterior tibial nerve, which was pulled down and 1 cc. of 1 per cent procaine hydrochloride followed by 1 cc. of 80 per cent alcohol injected into it. The nerve is divided and allowed to retract.

Dressings.—The amputation wound, depending, of course, on the clinical signs of the presence of infection, is not dressed preferably for from twelve to fourteen days. This allows tissue relationships to be undisturbed for such an interval that repair of the wound is sufficiently strong to prevent the stump components from separating. The old dictum of not lifting the stump off the bed or dressing the stump without support posteriorly has been closely followed, as my co-workers

and I have frequently demonstrated that this has prevented the soft parts from opening and falling away from the bones and from each other.

Particular care is taken in dressing the stump at operation. We have used a type of dressing that has consistently proved satisfactory. It is done as follows:

1. A strip of fine meshed gauze soaked in surgical solution of chlorinated soda (Dakin's solution) covers the suture line on each side of the drain.

Fig. 10.—The peroneus tertius, brevis and flexor hallucis longus have been separated from the fibula with curved scissors and retracted. The fibula is reamputated 1 inch above the end of the tibia. The anterior tibial crest is beveled for from ½ to 1 inch.

Fig. 11.—The deep fascia has not been sutured. The skin is sutured with interrupted dermal sutures and a rubber dam drain placed down to the dead space below the tibia.

2. Fluffed gauze covers the end of the stump, evenly diffusing the pressure.

3. A flamed mole-skin adhesive strip is placed on the posterior portion of the knee and crural regions partially surrounding the stump for one-half its circumference. The end of this strip distally is cut and folded so that a strip 1 inch wide is made to which by a small rope a 2 to 3 pound (0.9 to 1.4 Kg.) weight for traction can be applied through a pulley fixed to the end of the bed, as soon as the patient is returned to bed.

4. A cushiony pad covered with gauze smeared with ointment of boric acid on its inner surface is placed behind the distal third of the stump, between the adhesive strap and the skin.

5. The entire large dressing is bandaged snugly and evenly with from 2 to 3 five yard rolls.

6. Adhesive strips from 1 to 2 inches wide are placed spirally over the rolls, reaching well up on to the thigh in order to anchor the dressing.

This type of dressing has accomplished the following:

1. Its large size insures comfort and absorption of drainage without external soiling.

2. Even diffusion of pressure insures good tissue approximation.

3. Skin traction maintains the length of the soft parts and overcomes muscle spasm.

4. The stump with its dressing can be moved quite painlessly by using the traction strap as a support.

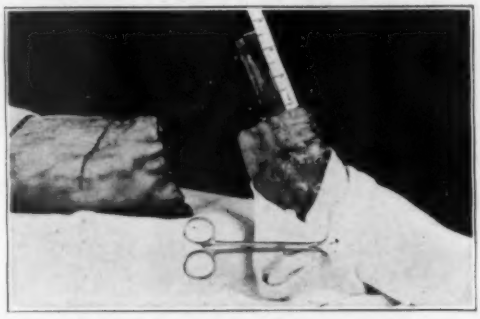

Fig. 12.—Lateral view of the stump. The black line represents the plane of the ends of the bones. The specimen shows the soft parts amputated 2¾ inches below the bones.

5. Motion of the stump within the dressing is not possible. When motion is permitted in the dressing, it has been found to be painful.

6. The dressing is maintained in place for from twelve to fourteen days comfortably.

7. Removal of drains is possible without taking the entire dressing down.

To remove a drain shortly after amputation, before the stump is to be dressed, we have found it useful to tie to the drain a piece of heavy silk string, bringing the end out into the dressing near the surface, yet covering it with gauze, where it can be easily found. By means of this string the drain can be withdrawn from the wound and dressing or from the wound only, leaving it in the large dressing, without disturbing that part of the dressing adjacent to the wound.

Subsequent dressings are done only as indicated. Meticulous care is urged, however, in dressing these stumps wherein infection lurks in the presence of a diminished blood supply.

Healing of the amputation stump is retarded by too frequent dressings. The repair process in these stumps is slow because of the diminished blood supply. Dressings rearrange healing tissue relationships; primary union of tissues in juxtaposition is interfered with when this relationship is changed by an unnecessary

dressing. Bacteria unable to proliferate in these approximated healing tissues may cause active infection following even minimal damage to tissues from manipulation while dressing. The stumps are always dressed with the foregoing facts in mind.

The fundamental principle of this operation is the minimum interence with the collateral blood supply. The amputation of both bones above the site of the severance of the soft parts leaves the ends of the bone well covered for from 3 to 4 inches, and after shrinkage, as seen three, six and twelve months later, there remains a painless movable soft stump for 2 or 3 inches beyond the ends of the bone. The blood supply, both collateral and peripheral, is so well maintained that ulceration such as that seen from stretching trauma about the ends of the true guillotine stumps has not been encountered.

The follow-up has not been sufficiently long to determine whether the incision on the anteromedial surface of the soft parts of the stump will continue to be painless and free from ulceration with weight-bearing on the condyles of the tibia, but cases followed for three and one-half years have not shown such trouble.

However, the follow-up in these cases to date, although relatively short (three and one-half years), has been uniformly good, and sufficient time has elapsed to have allowed a general recovery and stabilization of these patients from the depletion of their amputations.

REPORT OF ILLUSTRATIVE CASES

CASE 1.—*History.*—L. M., a Russian woman, aged 40, was admitted to the Presbyterian Hospital on Jan. 7, 1929, complaining of a sore right foot of two weeks' duration. She had lived in New York for eighteen years (fig. 13).

Two weeks before admission she noticed a fissure in the skin between the right first and second toes. This area swelled and became cyanotic, and she consulted her local doctor, who found sugar in her urine. She did not know she had diabetes.

On arrival at the clinic her urine showed dextrose 4 plus and a 4 plus ferric chloride reaction. She had an acetone breath. She had never been on a diet or taken insulin. Her past history was essentially unimportant, except for the following positive facts: All her life she had been a hard working woman. At the time of examination she was supporting three children. For the past three years she had worn glasses for reading. She had never previously been in a hospital. She had never been obese nor had her weight changed. There was no history of skin infection. Her catamenial history was normal.

On admission the temperature was 102 F.; the pulse rate, 120; respiration, 20, and blood pressure, 150 systolic and 90 diastolic. There was no family history of diabetes.

The right foot revealed cellulitis, gangrene and deep cyanosis of the great and second toes. The cellulitis extended up near the junction of the lower and middle thirds of the leg. Wound culture showed hemolytic streptococcus. The blood culture was negative.

The blood sugar was 2.81 Gm. per liter; the blood urea, 0.24 Gm. There were 27,100 white blood cells and 92 per cent polymorphonuclears.

For two days the patient was given a clysis of 1,500 cc. of 5 per cent dextrose with 25 units of insulin, which cleared the diacetic acid from her urine.

She was septic; the temperature was 102 F., and the pulse rate varied from 90 to 120. On the dorsal surface of the foot there was an area of dry gangrene, 8 by 10 cm. Pus discharged copiously from a sinus at the base of the great toe, on the plantar medial surface. There was no lymphangitis extending up the leg and no regional lymphadenitis. The dorsalis pedis and posterior tibial vessels were not felt in either foot. The right popliteal and the femoral vessels were palpable. The lungs and heart were functioning normally, and no pathologic sounds were heard. The radials were beaded.

The patient's collateral circulation was good, as evidenced by a warm skin down to her foot. Dextrose and insulin had reduced the sugar in the urine to 1 plus, and there were no ketogenic bodies in the urine, although the blood sugar was 2.8 Gm. per liter.

Operation.—Because of the severe infection and gangrene it was thought safest simply to rid the patient of the gangrenous area by guillotine amputation through the lower third of the leg. Fewer tissue spaces are opened there than when the

Fig. 13.—Condition of the right foot on admission.

amputation is made through the muscles of the middle or the upper third. A Gritti-Stokes amputation could subsequently be done if necessary. An amputation through the lower one third of the thigh might become necessary because of the degree of arteriosclerosis. The other leg and foot were warm. An infection might develop in the other foot and subsequently necessitate amputation. A bilateral Gritti-Stokes operation is not as useful as a Gritti-Stokes operation on one leg and an amputation leaving a knee joint on the other. She might have enough collateral circulation in the right leg to permit an amputation through the lower third. It was decided to operate immediately under ethylene as soon as permission was obtained.

The second day after admission, under ethylene anesthesia, a circular true guillotine amputation was done through the middle third of the right leg. The main vessels bled in spite of the calcification shown in the roentgenogram (fig. 17). The wound was left wide open. Amputation required eight minutes. Culture of the exudate from the foot at operation grew a nonhemolytic streptococcus and nonhemolytic Staphylococcus aureus. Anaerobic culture of the muscles at the site of the amputation showed no growth. Aerobic culture of the muscles grew hemolytic streptococcus and hemolytic staphylococcus.

Roentgenograms of the legs showed calcification in the vessels.

Pathology Report.—Gross: The specimen consisted of a foot amputated just above the ankle joint. On the dorsum of the foot, just above the base of the toes, was a rectangular black area measuring 5.5 cm. from side to side. At the lateral side of the foot it was 3.5 cm. wide; at the medial side, 2.5 cm. The surface was black and hard. On section the underlying tissues, especially toward the medial side of the foot, were extremely ragged and necrotic and contained a grayish-brown, semifluid, foul material. On dissecting the foot, the dorsalis pedis artery was found to be small. The wall appeared thickened and the lumen narrow, and in the wall there was a marked deposit of calcium which was more prominent in the upper part of the artery than in the lower. On sectioning the first metatarsal, the bone was found to be hard and white.

Microscopic: Sections through the edge of the blackened area were bordered by a thin tissue. At one end of the section this was markedly thinner than at the other end, where examination revealed the presence of a layer of dense connective tissue immediately beneath the skin, rather thickly infiltrated with polymorphonu-

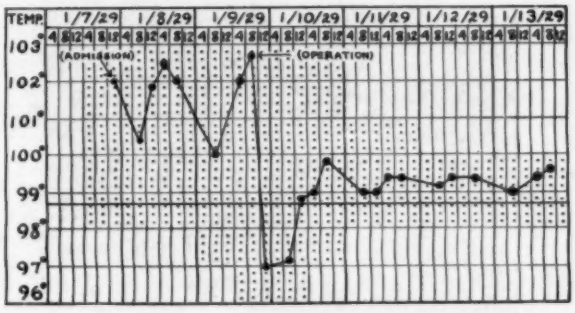

Fig. 14.—Chart showing drop in temperature following guillotine amputation of the right leg.

clear leukocytes and round cells and presenting many small deposits of brownish pigment. There were many lymphatic vessels distended with polymorphonuclear leukocytes. Below this tissue, there was more necrotic tissue thickly packed with polymorphonuclear leukocytes and round cells. In sections from the upper part of the dorsalis pedis, the intima was considerably thickened and contained many large deposits of calcium. In sections from the lower part of the dorsalis pedis, the intima was somewhat thickened, though not as much as in the upper part. The media was thickened and contained several large deposits of calcium. In sections from the first metatarsal, the bone cells were for the most part well preserved. In the marrow cavity, there were many scattered accumulations of polymorphonuclear leukocytes (G. H. Hunt).

The electrocardiogram made January 26 showed the following: sinus rhythm; ventricular rate, 118; P-R interval, 0.14; the P wave, upright in all leads; R_3, notched; S_1 and S_2, notched; T_1 and T_3, upright, and T_2, inverted. The rate was abnormally elevated. Notching of the Q-R-S complex in all three leads suggested slight myocardial involvement (K. B. Turner).

Course.—The first dressing was done eleven days after amputation. Up to this time the patient had been exceedingly well. Her temperature dropped dramatically from 102.8 F. to normal the day following amputation and remained normal subse-

quently (fig. 14). Her blood sugar stayed high for a week in spite of large doses of insulin. During the second week, on a diet of 100 Gm. of carbohydrate, 60 of protein and 50 of fat and 40 units of insulin she became sugar-free. The amputation wound showed more granulations in the lower than in the upper half. The ends of the tibia and the fibula were slowly covered by granulations. The wound was rather dry. From the fifteenth day wet dressings were applied in preparation for Thiersch grafts. The skin had retracted from ¼ to ½ inch (0.63 to 1.27 cm.), and the tissues were flush with the end of the tibia.

Sixteen days after amputation, following extraction of two teeth, the patient had an attack of circulatory collapse, bringing her blood pressure down to 40. There was difficulty in differentiating this from hypoglycemia, and unfortunately the blood sugar was not taken at this time; yet dextrose administered intravenously brought her out of collapse.

On February 8, thirty days after amputation, Thiersch grafts were applied to the stump. Six days after grafting, the stump was dressed and all but two of the grafts had sloughed off. By the second week after grafting, they had prac-

Fig. 15.—End of the guillotined right stump one year after Thiersch grafts had been applied twice. This subsequently had to be revised because of repeated ulcerations on the end of the stump. Revision was done by excising a portion of the tibia and fibula with the same technic as was used in a primary amputation.

tically all sloughed off. Fifty-seven days after amputation, Thiersch grafts were applied the second time. These took well.

On the forty-seventh day after amputation, the tibial cortex which protruded from the wound was rongeured off. The patient was discharged from the hospital on the seventieth day after amputation. The blood sugar was 1.68 mg. Thirty units of insulin and a diet of 150 Gm. of carbohydrate, 60 of protein and 50 of fat were given. Her urine was sugar-free. When the patient was discharged she was getting 30 units of insulin, the dosage having been decreased from a maximum daily dose of 60 units on admission. The stump was completely epithelized (fig. 15).

Infection about the teeth cleared up following multiple extractions.

Follow-Up.—Five months after amputation the skin was adherent to the end of the tibia; there was no pain. The patient had been wearing an artificial leg for one week. The stump was ready for the leg three and a half months after amputation, but it could not be obtained because of financial reasons. The diabetes was under control on a diet of 150 Gm. of carbohydrate, 60 of protein and 100 of fat and 15, 5 and 15 units of insulin.

One year after amputation the right artificial leg was entirely comfortable. The left dorsalis pedis and posterior tibial arteries were not palpable. The patient was referred for prophylactic treatment of the remaining foot.

Eighteen months after amputation, superficial ulceration on the lateral side of the second *left* toe 1 by 1 cm. was noted. An ulcer, 0.25 by 0.5 cm., had appeared on the right stump in the grafted area. The stump measured 25 cm. from the tibial tubercle to its end.

This case illustrates a frequent observation on stumps produced by guillotine operation through the lower one third of the leg; the stump was too long for the best type of prosthesis, and the skin over the tibial end was apt to be traumatized. The patient was wearing her artificial leg in spite of ulceration.

From July to September, 1930, the ulcer on her left second toe failed to respond to treatment at home and by the district nurse, and the patient was readmitted to the

Fig. 16.—Condition of the left foot before amputation.

hospital. The ulcer had existed on the lateral plantar surface of the second left toe for four and one-half months. The patient's temperature was 98.6 F.; the blood pressure, 95 systolic and 80 diastolic. The essential findings were ulceration of the second toe and an ulcer in the amputation stump. Two weeks after admission a small abscess appeared under the nail of the left great toe in spite of all the hospital care. Active hyperemia produced five minutes every two hours with the blood pressure cuff filled to 15 mm. below diastolic pressure on the thigh failed to help the local condition.

Second Operation.—On October 4, amputation of the left second toe and revision of the amputation stump of the right leg were done. A roentgenogram failed to show osteomyelitis. Under infiltration anesthesia with 0.5 per cent procaine hydrochloride the ulcer at the end of the right stump was excised and 3 cm. of the tibia and 4 cm. of the fibula was removed with bone forceps. The wound was partially sutured and treated with surgical solution of chlorinated soda; on the

second left toe laterally an ulcer 1 by 0.5 cm. had existed for five months which had not shown evidence of healing under a week of hospital treatment. This toe was amputated under infiltration anesthesia with procaine hydrochloride with a racket incision; the cartilage of the metatarsal joint was removed with a rongeur, and the wound was treated with surgical solution of chlorinated soda. The site of this amputation remained dry and black; ultraconservatism was tried because the patient had had one leg amputated and we were anxious to save the other foot, but it was in vain, and on October 20, sixteen days after amputation of the left second toe, a modified guillotine amputation was done on the left leg at the junction of the lower and middle thirds.

One hundred milligrams of procaine hydrochloride was introduced between the fourth and fifth lumbar vertebrae without difficulty. The anesthesia was complete

Fig. 17.—Roentgenogram showing calcification of the vessels on the right stump. A similar condition existed on the left.

and satisfactory. An amputation through the lower part of the leg as described in this paper was done. Careful hemostasis was done with fine plain catgut without taking mass ligatures. The posterior tibial artery was a solid calcified cord and bled very little. It was hardly necessary to ligate it. The anterior tibial artery was likewise calcified, but a little more patent than the posterior. The peroneal artery bled. There was little bleeding from the almost eburnated bones. The deep fascia was approximated over the tibial crest anteriorly throughout the wound to within the distal 2 inches. A rubber dam drain was placed down just posteriorly to the site of the amputated tibia. A long silk string was tied to its distal end so it could be removed from the wound without opening the dressing. The skin was closed with dermal sutures. The following note was made by Dr. B. C. Smith:

"The idea of this type of procedure is a modification of guillotine amputation in which the bones are amputated through the upper third of the leg and the soft

parts through the junction of the lower and middle. Whether or not this was a difficult case for the procedure because of the calcified posterior and anterior tibial vessels is hard to say. The patient has very little healing power. This method leaves a good long flap covering the bones distal to their ends. An attempt was made in doing the amputation to open as few tissues as possible; i. e., skin, subcutaneous tissue and muscles were sectioned in the same plane. The muscles were not dissected at all except where they were removed from the bone, thereby not interfering with whatever collateral circulation there has existed."

Pathology Report.—Gross: The specimen consisted of the lower left leg cut 32 cm. above the plantar surface of the heel and a piece of white tissue 4 cm. long and 0.5 cm. in width, said to be a piece of the tibial nerve. The amputation showed 10 cm. of bare tibia and fibula above the site of incision. The second toe had been removed, leaving a deep ulcerated cleft between the third and great toe. The ulcer was 1 cm. deep, surrounded by soft necrotic, blackish material with a distinct line limiting this from the more normal tissue proximally. The third toe was bluish, and the ulcerated area extended over to expose the tendon of this toe. The two other toes appeared relatively normal, and there were no other areas of changes in the skin grossly. A complete dissection of the anterior and posterior arteries was done following down the dorsalis pedis, including the ramifications of the digital arteries where they became lost in the ulcerated area. The vessels were alike in consistency, being very brittle, entirely without elasticity, considerably thickened and containing a great deal of hard, gritty, calcium deposits.

Microscopic: A section through the margin of the ulcer showed a fairly definite line of demarcation between the relatively normal epithelium proximally and the sequestrated structureless epidermis distally. Beneath the skin the line was not so sharply defined. The subcutaneous tissue was infiltrated sparsely with polymorphonuclear leukocytes for some distance proximally and distally became more dense until there was a zone of indistinguishable necrotic material. There was also considerable perivascular infiltration about the small thickened vessels.

Sections of the arteries showed a marked degree of arteriosclerosis, with the greatest changes in the larger vessels. In the upper portion of the posterior tibial artery the lumen was entirely filled with an organized thrombus with little effort at recanalization. It contained a moderate amount of productive, slightly inflammatory granulation tissue in the subintimal layer, and beyond this and extending into the media there was an entire layer of calcification, which in some places had undergone ossification. The musculature of the media was almost entirely replaced by connective tissue, and there was also considerable fibrosis of the adventitia. The lumen in the lower part was very much narrowed but was not thrombosed so that collateral vessels must have been present. All the other vessels showed calcification and considerable fibrosis. The lumen of the dorsalis pedis contained a recent thrombus which had no evidence of beginning organization (Dr. C. J. Kraissl).

Amputation was necessitated by evidences of maintained infection at the site of amputation of the second left toe, which six days after operation was black and dry. Amputation was done by the modified guillotine technic sixteen days after amputation of the toe.

The temperature dropped to normal by the sixth day after amputation of the left leg and continued there. The blood sugar rose to 2 Gm. per liter with the patient on from 40 to 45 units of insulin and a diet of 150 Gm. of carbohydrate, 80 of protein and 100 of fat. Her blood sugar had decreased to 1.17 Gm. per liter thirty-three days after amputation.

The first dressing was done on the tenth day and the sutures were removed on the thirteenth day. On the seventeenth day a slight separation of the edges of the skin occurred. On the twenty-fourth day the edges of the skin had separated more, and there was a granulating area 1 cm. wide in the lower two thirds of the wound. The right stump had completely epithelized.

Fig. 18.—Amputation stumps two and one-half years after guillotine amputation of the right stump and ten months after amputation of the left stump by foregoing technic. Note the difference in the length of the parts covering the two stumps.

Fig. 19.—End view of the left amputation stump (author's technic).

On discharge, she was on 8 units of insulin; she had required 45 during her stay in the hospital. A diet of 100 Gm. of carbohydrate, 60 of protein and 50 of fat was given. The blood sugar was 1.17 mg. The urine was normal.

Follow-Up.—Eleven months after amputation of the right leg and two months after amputation of the left, both stumps were healed and painless. The patient was walking with an artificial right leg and a crutch, and was to secure the artificial left leg.

Fourteen months after amputation of the right leg and five months after amputation of the left, the right bone stump was 21 cm. long from the tibial tubercle to the end of the soft parts (true guillotine amputation). The left bone stump was 9 cm. from the tibial tubercle and was covered by a 4 inch pad of soft parts. She was wearing two artificial legs and was able to do about 30 per cent of her housework. The results for the right leg were 75 per cent normal anatomically, 100 per cent symptomatically and economically; the results for the left leg were 100 per cent in all three respects.

On July 28, 1931, eighteen months after true guillotine amputation of the right leg and eight months after modified guillotine amputation of the left leg, the patient stated that she liked the artificial left leg better, but I believe this is due to the stump (figs. 18 and 19). There are no ulcers or any pain. She walks with a cane a distance of one-half block. Her result was 100 per cent anatomically,

Fig. 20.—Condition of the left foot on admission.

symptomatically and economically for both legs. The blood sugar was 1.51 Gm. The diet was 100 Gm. of carbohydrate, 60 of protein and 50 of fat. The urine was normal.

Ophthalmologic examination revealed diabetic retinitis, retinitis proliferans, arteriosclerosis (marked) and detachment of the retina of the left eye.

On Jan. 8, 1932, two years after guillotine amputation of the right leg through the lower third and fourteen months after revision of the right, true guillotine stump, the patient walked with two artificial legs, doing her housework, and walked as far as three blocks a day outdoors without stopping. The left stump was the most comfortable one. The right has remained healed after the revision.

Case 2.—*History.*—R. L., a Jewish woman, aged 68, was admitted to Presbyterian Hospital on July 22, 1930, complaining of pain in her second left toe and periods of discoloration with diminished sensation of the left toe for three years (fig. 20).

Three years before admission, while walking, her left foot suddenly became numb and painful. Up to this time she had noticed nothing wrong with her foot. She did not consult her doctor. Two months later a chiropodist pared a corn on her left third toe; it became so painful that she went to a doctor who incised it and found pus. This toe did not heal. Shortly thereafter the left, second and great toes began to change color. She treated them herself with mercurochrome-220 soluble. In spite of physical therapy which she received at a hospital, the great toe became more discolored. No active treatment was given for one year, at the end of which time the fourth toe dropped off. The remaining toes were gradually blackened. During this period she walked on her feet about her housework, but she was unable to walk for four months before admission. The family history did not reveal diabetes. Her best weight twelve years before admission was 172 pounds (78 Kg.). Her weight on admission was 95 pounds (43.1 Kg.).

Fig. 21.—Condition of the right foot before amputation.

Examination.—Physical examination revealed a rather thin woman of 68, who was not suffering from much pain. The important positive findings were: She had large tonsils not in an acute condition. The lungs were normal. The heart was regular, no enlargement made out, and there were no murmurs. The wall of the abdomen was flaccid and a scar from an operation in the lower left median area had healed firmly. The blood pressure was 186 systolic and 85 diastolic. Her local condition was one of gangrene of the left first, second and third toes. The fourth toe had been spontaneously amputated, and there were cellulitus and edema of the dorsum of the foot. There was pink discoloration of the skin of the distal two thirds of the whole of the foot. The dorsalis pedis and posterior tibial arteries were not palpable in either foot. Both popliteal and femoral arteries were palpable, but the pulsations were less than normal. The patient did not know she had diabetes. On admission the blood sugar was 1.78 Gm., the carbon dioxide-combining power of the plasma was 58 per cent by volume, and the urine showed 2 plus dextrose. The foot emitted a foul odor.

Operation.—The day following her admission, under spinal anesthesia (1 cc. of a proprietary procaine preparation in the fourth lumbar space), a circular flap amputation was done by Dr. R. Moore through the lower third of the left leg 4 inches above the malleoli, both bones being amputated 3 inches higher than the soft parts. Injection was not made into the nerves. The tissue cultures of the vessels at operation which did not bleed were negative. Two catheters were placed in each angle of the wound down to the site of the amputated bones for drainage and surgical solution of chlorinated soda was used.

Pathology Report.—Gross: There was dry gangrene on the great toe; black dry gangrene on the second toe and gangrene on the plantar surface of the third toe. The skin on the distal two thirds of the dorsal and plantar surfaces of the foot was macerated. The fourth toe had been amputated. The fifth toe was not discolored.

Microscopic: On section of the anterior tibial artery the lumen was found to be markedly narrowed by a process of fibrosis in the intima and media. The veins

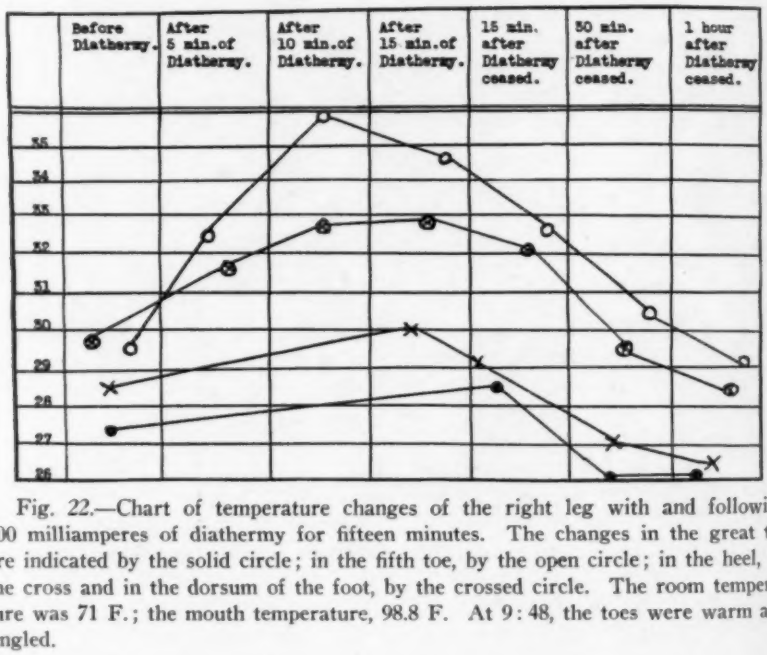

Fig. 22.—Chart of temperature changes of the right leg with and following 200 milliamperes of diathermy for fifteen minutes. The changes in the great toe are indicated by the solid circle; in the fifth toe, by the open circle; in the heel, by the cross and in the dorsum of the foot, by the crossed circle. The room temperature was 71 F.; the mouth temperature, 98.8 F. At 9:48, the toes were warm and tingled.

also showed intimal thickening. The posterior tibial artery was entirely occluded and consisted of simply a fibrous cord, in the wall of which was a piece of bone. The dorsalis pedis shared in the same process but contained a small lumen and also had a piece of bone in the media. The veins here were also thickened.

Section through the tissues around the base of the great toe showed them to be necrotic, especially on the plantar surface, where there was a denser infiltration with polymorphonuclear leukocytes. Aggregations of leukocytes were also seen in the dorsum but were less marked and located chiefly around the vessels near the bone. Several of the vessels contained thrombi which were undergoing organization. The others contained masses of leukocytes.

Course.—The diet before operation was 100 Gm. of carbohydrate, 60 of protein and 50 of fat with 10 units of insulin. The day following operation 40 units of

insulin and 125 Gm. of carbohydrate were given, and the blood sugar dropped to 1.09 Gm. per liter.

Spinal anesthesia has not been found to affect the blood sugar in diabetes.

During the remainder of her hospital stay, the patient required only 6 units of insulin daily for two weeks. Her diet was raised to 150 Gm. of carbohydrate, 60 of protein and 100 of fat, and she required no insulin. Her blood sugar was 1 Gm. per liter on discharge. She had essentially arteriosclerotic dry gangrene with mild diabetes.

Following amputation, her temperature rose to 101.6 F., reaching normal in three days, and stayed so during her stay of sixty-seven days in the hospital.

A roentgenogram of the foot before operation showed calcification of the dorsalis pedis and arterial branches of the toes. There was no evidence of osteoporosis or osteomyelitis.

Follow-Up.—Three months after amputation of the left leg the tibia was 16 cm. from the tubercle to the end of the stump. The circumference of the stump was 21 cm. at the tibial end. A goodly amount of the soft parts covered the bone and

TABLE 1.—*Results of Whirlpool Bath* *

	Left Leg								
	Before Bath	Bath for 15 Min.	5 Min. After	10 Min.	15 Min.	20 Min.	30 Min.	1 Hr.	2 Hr.
Great toe	25.0	34.7	33.1	32.4	32.0	32.0	31.7	30.7	26.9
Fifth toe	26.0	34.3	33.4	33.0	32.4	32.0	31.6	30.6	26.8
Heel	28.0	34.3	34.4	34.2	34.0	33.8	33.8	33.5	30.9
Dorsum	30.4	35.4	34.3	34.0	33.8	33.8	33.6	32.7	30.4
Lower one third leg	28.4	35.5	34.9	34.3	33.4	33.6	33.6	31.9	30.4
Lower one third thigh	29.8	30.9	30.1	31.0	31.0	31.4	31.3	32.1	30.9
Mouth temperature		98.4							98.4

* The temperature with the exception of mouth temperature is given in centigrade.

extended 3 inches beyond it. The patient was ready for an artificial leg. A prosthesis made by the Institute for Crippled and Disabled was being worn four months after amputation.

In nine months slightly reddened areas appeared at the site of weight-bearing in the cuff. This was satisfactorily adjusted. The patient complained of pain in her right foot at this time which showed no change since the previous examination.

In February, 1931, she showed areas of necrosis on the medial side of the distal end of the right great toe and the distal end of the right second toe. The foot was warm, and there was no obvious cellulitis about the areas of necrosis. The pain in the foot was exquisite.

On March 10, 1931, there was an area of gangrene on the right great toe and cellulitis of the second toe. The surface temperatures of the right foot were practically normal, which in the presence of areas of gangrene indicated a fairly active superficial collateral circulation (fig. 21).

The surface temperatures after diathermy were compared with surface temperatures taken after a whirpool bath, the lower two thirds of the leg being immersed in water at 104 F. for thirty minutes. The results are shown in figure 22.

The amount of rise in the surface temperature after from fifteen to thirty minutes in a whirlpool bath at 110 F. is shown in table 1. The bath was started at 10:15 a. m. with a water temperature of 106 F.

Operation.—On March 27, 1931, under gas oxygen anethesia, amputation through the lower third of the right leg was done by my method for arteriosclerotic

Fig. 23.—Roentgenogram of the right amputated lower third of the leg after injection of 15 per cent bismuth oxide chloride under 20 pounds of pressure, showing a small amount of collateral circulation and no visible main peripheral vessel.

Fig. 24.—Superficial skin slough on the right stump twenty-eight days after amputation.

gangrene of the right great, second and third toes. The posterior tibial vessel did not bleed, but the posterior interosseous and anterior tibial arteries spurted. Bleeding vessels and points in the cut muscles were ligated, care being taken that mass ligatures were not used. The skin was approximated with interrupted dermal sutures, between which in the middle of the suture line a silk drain was placed down to the tibia.

During this second admission the blood sugar varied between 1 and 1.6 Gm. per liter. The patient was discharged on the thirty-first day after amputation with the wound healed. She required no insulin on a diet of 100 Gm. of carbohydrate, 60 of protein and 50 of fat. A roentgenogram before operation showed calcification of the vessels of the leg and toes, dorsum and plantar surface of foot.

Follow-Up.—Ten months after amputation of the left leg, the artificial leg still irritated the stump at the site of weight-bearing on the cuff. This was apparently due to the inability to have it adjusted because of hospitalization with the second amputation.

Fig. 25.—Right stump eleven months and left stump nine months after amputation. The right stump shows a small area of necrosis from which a piece of tendon was removed. This area healed in a week.

On June 30, three months after amputation of the right leg, there appeared a small piece of sloughing tendon at the lower angle of the soft part stump. This sloughed away and epithelized following a week of treatment in the hospital.

On July 8, 1931, four months after amputation, the patient wore an artificial leg on the left stump but was not able to purchase the right artificial leg. Her general condition was excellent, and she has a remarkable attitude toward her problem (fig. 25).

On Jan. 8, 1932, ten months after amputation of the right leg and eighteen months after amputation of the left, both stumps were firmly healed and painless. The patient walked about the house with two artificial legs with the aid of a cane. There was a long soft part stump covering the end of the right stump which was amputated by the modified guillotine technic, and this was more comfortable than the left leg where there was a similar pad of the small part covering the ends of the bone.

Two years after the amputation of the right leg she comfortably wore both artificial legs. The right stump was the more comfortable. She walked one or two blocks without the aid of a cane.

CASE 3.—*History.*—D. I., a Jewish woman of 69, complaining of gangrene of the right and left great toe of three months' duration, was admitted to the Presbyterian Hospital on Jan. 26, 1931. The family history did not reveal any diabetes. She was known to have had diabetes for six years. Glycosuria was discovered following a complaint of pruritis vulvae to her local doctor. At this time, in 1925, the glycosuria cleared on a diet. The urine had been tested repeatedly during the last six years and found to be normal. For the past three years she had had cold toes and cramps in her right calf on walking from two to three blocks; these were relieved by resting for from three to five minutes.

Four months previously she noticed a blue spot on her right great toe. Soon afterward a similar area appeared on her left great toe. The blue spot on the right gradually involved the whole toe and similar splotches appeared on the other

Fig. 26.—The right foot on admission showing gangrene, for which the leg was amputated by my technic through the lower third.

toes. Soon afterward, black areas appeared in the skin on the dorsum of the right foot. She had put off medical care because of fear of amputation.

Examination.—On admission she was in great pain. Physical examination revealed the following relevant findings (fig. 26): The patient was a well developed and well nourished woman of 69, weighing 133 pounds (60.3 Kg.). She was 5 feet (152.4 cm.) tall. The blood pressure was 160 systolic and 74 diastolic. There was moderate arcus senilis. On percussion the left border of the heart was found 12 cm. from the midline in the fifth space to the left. The apical systolic murmur was transmitted into the axilla. A rough systolic murmur was heard over the aortic site. The lungs were normal. The abdomen was obese. The liver was felt at the costal margin. The radial and brachial arteries were hardened. The popliteal arteries were palpable in both legs. The dorsalis pedis and posterior tibial arteries were not palpable in either extremity. Pelvic and rectal examination gave negative results.

Before operation culture from the gangrenous great toe grew a nonhemolytic streptococcus, Staphylococcus albus and B. coli-communior.

On January 29, the lateral side of the fourth right toe presented a foul sloughing area 2 by 2 cm., communicating with a sinus in the fourth web, going into the lumbrical canal. The line of demarcation of the great toe was slightly moist. There was a cellulitic blush over the skin of the plantar distal third of the foot. No lymphangitis was present. There was less cellulitis about the areas on the dorsum of the foot. The blood sugar was 1.13 Gm. per liter. The urine was normal. The patient now required a sedative for the pain. The phenolphthalein test was 35 per cent. The temperature was 101 F. There were 4,400,000 red blood cells, 90 per cent hemoglobin, 8,000 white blood cells and 72 per cent polymorphonuclears. Amputation was advised as the infection was threatening and any operation locally would probably only accelerate and not cure it.

The surface temperatures on January 29 are shown in table 2.

The temperatures in table 2 are normal and represent a generous superficial collateral circulation. This is often noted in this type of gangrene, in spite of which sufficient blood supply does not exist for viability of the extremity.

TABLE 2.—*Surface Temperatures Read with a Tycos Dermatherm* *

	Right	Left
Great toe	Dry gangrene	30.2
Second toe	Ulcerated	30.2
Third toe	31.4	30.7
Fourth toe	31.4	30.9
Fifth toe	31.4	30.4
Dorsum of foot	Black necrotic area, 32.4	31.4
Ball	31.4	31.7
Concavity	31.4	31.7
Heel	31.4	31.7
Lower one third of leg	31.8	31.8
Middle one third of leg	32.4	32.8
Upper one third of leg	33.2	32.2
Lower one third of thigh	33.0	33.9
Middle one third of thigh	33.0	33.9
Mouth temperature	98.6 F.	
Room temperature	74.0 F.	

* The temperature, except room and mouth temperatures, is given in centigrade.

The effect of diathermy on the surface temperatures of her remaining left foot was studied as follows:

The toes were covered with saline-soaked gauze and an electrode bandaged placed over this. The other electrode was placed as a cuff just below the knee and 200 milliamperes of current was run through the electrodes for fifteen minutes. Three minutes after diathermy was begun, the patient stated she had a sensation of slight warmth in her leg.

On January 27, a roentgenogram of the legs and feet showed diffuse calcification of all the vessel walls, more marked in the smaller vessels, suggesting generalized arteriosclerosis. The joints of the feet showed evidence of osteo-arthritis. There were numerous semicalcified, rounded shadows lying in the superficial tissues just anterior to the tibiae suggesting calcified phleboliths.

Operation.—On January 30, a modified guillotine amputation through the lower third of the right leg was done, gas and oxygen anesthetic being used. The duration of the operation was twenty-seven minutes. There was a little bleeding from the anterior tibial artery which was partially calcified and a little from the posterior tibial. There was a spurter in the posterior tibial nerve. The nerve was pulled down for 2 inches and procaine hydrochloride with 1 cc. of 95 per cent alcohol injected

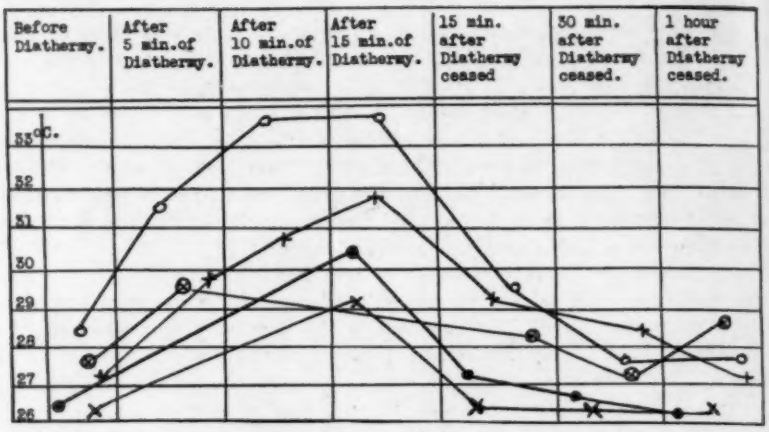

Fig. 27.—Chart of temperature changes in the left leg before and following diathermy of 200 milliamperes for fifteen minutes. One electrode was placed over the toes and the other below the leg. The room temperature was 74 F.; the mouth temperature, 98.6 F. The changes in the various parts are indicated as follows: the dorsum of the foot, the circle; the lower one third of the leg, a plus sign; the heel, a crossed circle; the great toe, a solid circle, and the fifth toe, a times sign.

Fig. 28.—Right stump seventy-four days after amputation showing superficial skin necrosis on the suture line. This was completely healed two weeks later.

into it. The vessel in the nerve had to be ligated. The anterior and posterior tibial artery and vein were ligated separately. There were no mass ligatures used. The tendons of the peroneal muscles were cut away. The skin was sutured with interrupted dermal sutures, and a small tampon drain with silk on the outside, one strip of iodoform and one strip of plain gauze were placed in the space anterior to the soleus muscle at the end of the tibia, because of oozing from the bone and the fact that the lymphatics through this region were probably infected. Dressing was put on with posterior adhesive strap to the skin for traction extending up to the knee. (Dr. B. C. Smith.)

Course.—Following amputation, the blood sugar rose to 1.73 Gm. per liter and a plus-minus glycosuria existed for a week. This was controlled by 3 units of insulin for six weeks. On discharge, seventy-nine days after amputation, the patient was sugar-free. The blood sugar was normal, and insulin was not being given.

The amputation wound was first dressed on the third day and a slight discoloration of the skin of the suture line was noted. A portion of the Mikulicz drain was removed. Culture of the amputation stump at this time grew hemolytic Staphylococcus aureus and hemolytic B. subtilis. The patient developed a small sacral decubitus, which healed with nursing care. Acute conjunctivitis developed twenty-four days after operation. By the twenty-fourth day the skin of the end of the stump had sloughed away for from 1 to 2 cm. on each side of the suture line. A granulating surface there prolonged complete healing of the wound. Collateral circulation of the skin at the amputation site was not sufficient to keep it viable following the injury associated with trauma of amputation.

The patient had rather severe cerebral sclerosis and remained rather disoriented and depressed for about three weeks after operation. The amputation stump epithelized slowly at the site of the skin slough in the suture line, but it completely healed by the seventy-ninth day. She remained in the hospital seventy-nine days because of her debility and mental lack of attempt to help herself to get well.

Follow-Up.—The patient began wearing an artificial leg eight months after amputation. This delay was due to infection in her other foot keeping her in a chair. The stump was ready for the prosthesis three months after amputation. The stump has been painless. No ulcerations have occurred, and she has now walked with her artificial leg for four months.

NOTE.—June 20, 1933: For three and one half years following amputation of the right leg, the stump has remained symptomless. The patient has worn her artificial leg for three years. She is now in Presbyterian Hospital with gangrene of the remaining foot, and amputation by the same technic will be performed as soon as she grants permission.

130 East Fifty-Sixth Street.

EFFECT OF MORPHINE ON THE MOVEMENTS OF THE SMALL INTESTINE AND SPHINCTER MUSCLES

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It is generally believed among physicians today that the effect of morphine on the intestine in the doses commonly used is to stop peristalsis and put the bowel at rest. This belief may be due to the results obtained in earlier experiments on isolated intestinal segments, on anesthetized animals or with improper doses of morphine. In the light of recent work it appears quite evident that the effect of morphine on the intestine is one of stimulation and not one of paralysis.

Those who have found paralysis of the small intestine after the administration of morphine are Legros and Onimus,[1] Nothnagel,[2] Leubuscher,[3] Katsch,[4] Meissner,[5] Zunz and Gyorgy,[6] Ohno [7] and Garry.[8] Those who have found that morphine stimulates the small intestine are Nasse,[9] Pal,[10] Popper,[11] Trendelenburg,[12] Behan,[13] Macht,[14] Uhlmann

From the Department of Surgery, University of Kansas School of Medicine.

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14. Macht, D. I.: Action of Opium Alkaloids on Smooth Muscle, J. Pharmacol. & Exper. Therap. **11**:389, 1918.

and Abelin,[15] Baur,[16] Tscherkess,[17] Gordonoff,[18] Plant and Miller,[19] Gurber and Robinson,[20] Dreyer,[21] Dvorak and his associates [22] and Wilen and Dragstedt.[23]

A few of the aforementioned authors merit special consideration, since they have secured results with the intestine under as nearly normal conditions as possible. Pal,[10] in 1900, appears to have been the first to record the contractions of the intestine in situ by means of a balloon in the intestine. He observed the effect of morphine on curarized dogs in doses of from 0.02 to 0.1 Gm. for a dog weighing from 6 to 8 Kg. The tone and the peristaltic movements of the small intestine were increased. Plant and Miller [19] prepared dogs with Thiry-Vella loops and made kymographic records of the small bowel. They found an increase in tone, an increase in the amplitude of segmentation movements and an increase in the amplitude and frequency of peristaltic waves. With doses of 0.5 mg. per kilogram, the effect disappeared in from five to eight hours, while with large doses of 5 mg. per kilogram, the duration of effect was twelve hours or more. In a man with a scrotal hernia, the number of contractions of the small intestine was increased by morphine. Gruber and Robinson,[20] also working on dogs with Thiry-Vella loops, noted essentially the same results as Plant and Miller with the use of morphine. Large doses decreased the general tonus and in some cases increased the force of rhythmical contractions. Dreyer,[21] by using the balloon method in cats, found that morphine in

15. Uhlmann, F., and Abelin, J.: Beiträge zum Opiumproblem, Ztschr. f. exper. Therap. **21**:58, 1920.

16. Baur, M.: Studien zur Frage einer einheitlichen Reaktion des Dünndarmes verschiedener Säugetiere auf darmwirksame Alkaloide, Ztschr. f. d. ges. exper. Med. **44**:540, 1925.

17. Tscherkess, A.: Zum Mechanismus der Morphiumwirkung auf den isolierten Dünndarm, Ztschr. f. d. ges. exper. Med. **48**:731, 1925.

18. Gordonoff, T.: Ueber die Wirkung der Morphium Codein Kombination auf den Magendermkanal, Arch. f. exper. Path. u. Pharmakol. **105**:287, 1925.

19. Plant, O. H., and Miller, G. N.: Effects of Morphine and Other Opium Alkaloids on the Muscular Activity of the Alimentary Canal: Action on the Small Intestine in Unanesthetized Dogs and Man, J. Pharmacol. & Exper. Therap. **27**: 361, 1926.

20. Gruber, C. M., and Robinson, P. I.: Intestinal Activity in Unanesthetized Dogs as Influenced by Morphine and by Papaverine, J. Pharmacol. & Exper. Therap. **37**:101, 1929.

21. Dreyer, N. B.: Effect of Some Opium Alkaloids on Intestinal Movements in Cats, J. Pharmacol. & Exper. Therap. **36**:477, 1929.

22. Dvorak, H. J.: Carlson, H. A.; Erickson, T. C.; Smith, V. D., and Wangensteen, O. H.: Influence of Morphine on Intestinal Activity in Experimental Obstruction, Proc. Soc. Exper. Biol. & Med. **28**:434, 1931.

23. Wilen, C. J., and Dragstedt, C. A.: Action of Morphine on the Intestine in Peritonitis, Proc. Soc. Exper. Biol. & Med. **28**:1056, 1931.

doses of 4 mg. per kilogram increased the tone and excursion of the recording kymograph lever. Dvorak and his associates [22] studied the effect of morphine on the human intestine by inserting a balloon into patients who had an ileostomy. After giving 10 mg. of morphine intravenously, an increase in tone and peristaltic waves was recorded. Similar results were obtained with ileostomies and colostomies on dogs with a dosage of 20 mg. of morphine given intravenously. The increase in activity could be easily determined by auscultation. Dogs in which obstructions were produced showed essentially the same results after the administration of morphine as those with normal bowels. With 50 mg. of morphine the intestinal noises were not so loud as with smaller doses. Wilen and Dragstedt [23] produced experimental peritonitis in dogs and recorded the results with a balloon placed in the bowel or in Thiry-Vella loops. Observations were also made on patients with peritonitis by auscultation of the abdomen. Both experimental and clinical observations showed that morphine increased the intestinal activity.

That morphine causes a spasm of the sphincters is agreed by all who have studied the subject. A great many experiments have been made on animals and a considerable number on human beings, and the emptying time has been prolonged several hours in the average case. Hirsch,[24] Baas,[25] Krylow,[26] Magnus,[27] Van den Velden,[28] Padtberg,[29] Arnsperger,[30] Schwenkenbecher and his co-workers,[31] Schwenter,[32]

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24. Hirsch, A.: Zur Kenntnis der Wirkung des Morphins auf den Magen, Centralbl. f. inn. Med. **22**:33, 1901.

25. Baas, K. H.: Ueber die Resorption von Jodkalium in menschlichen und tierischen Magen und über den hemmenden Einfluss des Morphins auf die Magenentleerung, Deutsches Arch. f. klin. Med. **81**:455, 1904.

26. Krylow, N. W.: Ueber den Einfluss des Morphins auf die Fortbewegung des festen Magendarminhaltes hungernder Kaninchen, Arch. f. d. ges. Physiol. **102**: 287, 1904.

27. Magnus, R.: Die stopfende Wirkung des Morphins, Arch. f. d. ges. Physiol. **122**:210, 1908.

28. Van den Velden: Zur Pharmakologie der Magenmotilität, München. med. Wchnschr. **56**:1667, 1909.

29. Padtberg, J. H.: Der Einfluss des Magnesiumsulfats auf die Verdauungsbewegungen, Arch. f. d. ges. Physiol. **129**:476, 1909.

30. Arnsperger, H.: Die Wirkung des Morphins auf die motorische Funktion des Magen-Darm-Kanals des Menschen, Verhandl. d. deutsch. Kong. f. inn. Med. **27**:333, 1910.

31. Schwenkenbecher, Alwens and Rauth: Wirkung einiger Opiumalkaloide und Opiumalkaloidkombinationen auf Magen und Darm, in Faust, E. S.: Ueber kombinierte Wirkungen einiger Opiumalkaloide, München. med. Wchnschr. **59**: 2489, 1912.

32. Schwenter, J.: Ueber Verdauungsversuche mit Opium, Morphium, Pantopon und morphinfreiem Pantopon, Fortschr. a. d. Geb. d. Röntgenstrahlen **19**:1, 1912.

Mahlo,[33] Stierlin and Schapiro,[34] Katsch,[35] Macht,[36] Gordonoff [18] and Thomas [37] have found an increased emptying time of the stomach after the administration of morphine. Of the foregoing investigators, Magnus, Arnsperger and Stierlin and Schapiro have found an increase in the emptying time of the ileum.

The foregoing reports indicate that a general review and revision of our ideas concerning the effect of morphine on the gastro-intestinal tract are advisable. Experiments were planned partially to review the work of Plant and Miller, to determine the effect of morphine on the obstructed small intestine under the most favorable conditions and to study the action of morphine on the pyloric and ileocecal sphincters.

EXPERIMENTS

Effect of Morphine on the Small Intestine.—For the purpose of studying intestinal activity after the administration of morphine sulphate, five dogs were prepared with Thiry-Vella loops of the upper jejunum and five dogs with Ivy-Mann enterostomies as previously described.[38] When healing had occurred, tracings of the intestine before and after the administration of morphine sulphate were obtained by the use of the Brodie bellows with an air pressure medium at a constant measured pressure. All morphine was given subcutaneously. Obstructions were then made in the upper jejunum 15 cm. below the ligament of Treitz, and the effect of a daily dose of morphine on the normal intestine of the dogs with Thiry-Vella loops and on the obstructed intestine of the dogs on which Ivy-Mann enterostomies had been performed was studied.

Morphine in small and moderate doses increased the tonus, the amplitude of segmentation movements and the amplitude and frequency of peristaltic waves in the jejunum and ileum of the dogs (fig. 1). The jejunum showed the more marked response. Morphine in doses of

33. Mahlo, A.: Ueber die Wirkung des Opiums auf den menschlichen Magen-Darm-Kanal, Deutsches Arch. f. klin. Med. **110**:562, 1913.

34. Stierlin, E., and Schapiro, N.: Die Wirkung von Morphin, Opium und Pantopon auf die Bewegungen des Verdauungstraktus beim Menschen und beim Tier, München. med. Wchnschr. **59**:2714, 1912.

35. Katsch, G.: Der menschliche Darm bei pharmakologischer Beeinflussung seiner innervation, Fortschr. a. d. Geb. d. Röntgenstrahlen **21**:159, 1914.

36. Macht, D. I.: The Action of Opium on the Digestive Tract, Am. J. M. Sc. **154**:874, 1917.

37. Thomas, J. E.: The Action of Adrenalin on the Pyloric Sphincter, Proc. Soc. Exper. Biol. & Med. **23**:748, 1926.

38. Mann, F. C., and Bollman, J. L.: Method for Making Satisfactory Fistula at Any Level of Gastro-Intestinal Tract, Ann. Surg. **93**:794 (March) 1931. Scott, H. G., and Ivy, A. C.: Jejunal Alimentation: Experimental Study in Dogs, ibid. **93**:1197, 1931. Orr, T. G.: The Action of Sodium Chloride on the Small Intestine, ibid. **94**:732, 1931.

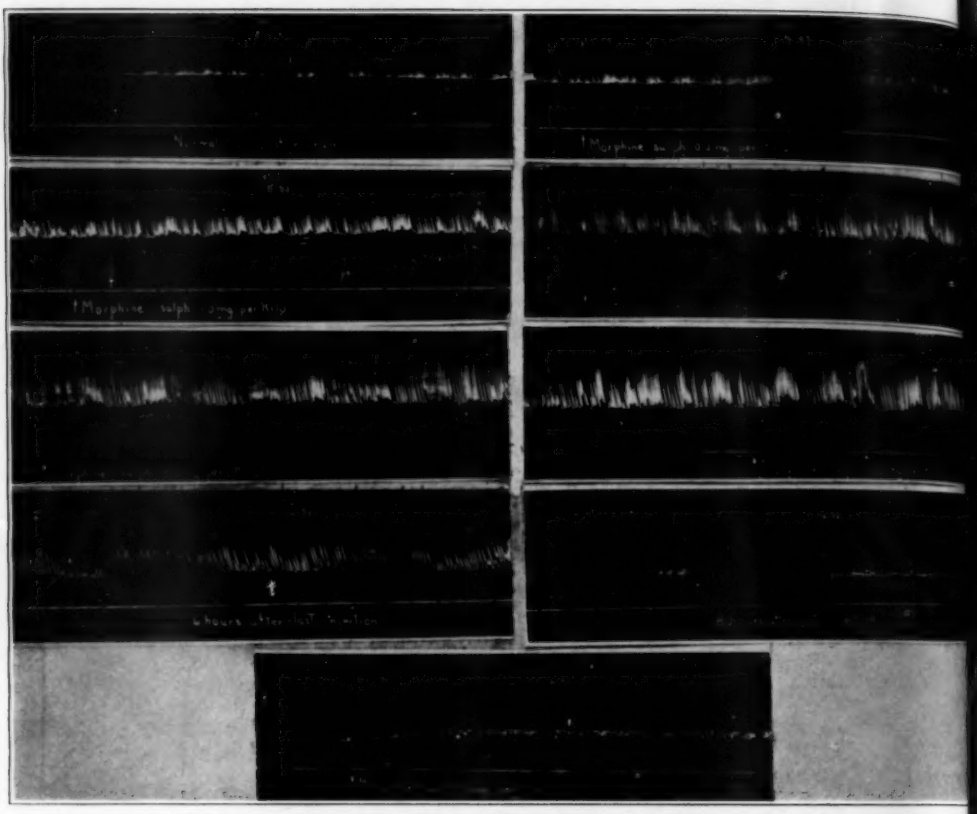

Fig. 1.—Kymographic tracing of jejunum from Thiry-Vella loop, showing effect of increasing doses of morphine when given hypodermically. The intestine showed some activity eighteen hours after the last injection.

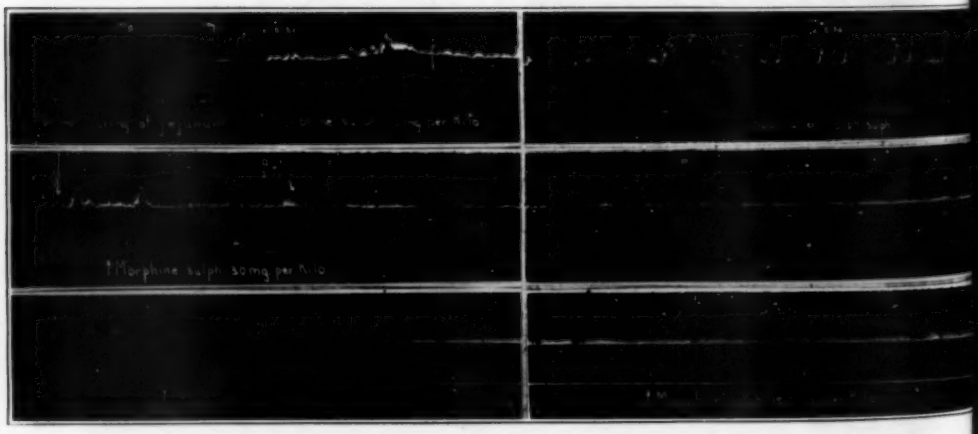

Fig. 2.—Kymographic tracing of jejunum from Thiry-Vella loop after the giving of large doses of morphine hypodermically. The larger doses caused a decrease in peristalsis, but did not diminish the rhythmic contractions.

from 3 to 5 mg. per kilogram stopped peristalsis and somewhat decreased the tone without affecting segmentation movements (fig. 2). Very large doses increased the amplitude of the segmentation movements, but peristalsis did not return. The duration of the effect of morphine was about six hours for the small doses (0.5 mg. per kilogram) and twelve hours for the larger doses (5 mg. per kilogram). The administration of morphine to dogs with Thiry-Vella loops or with

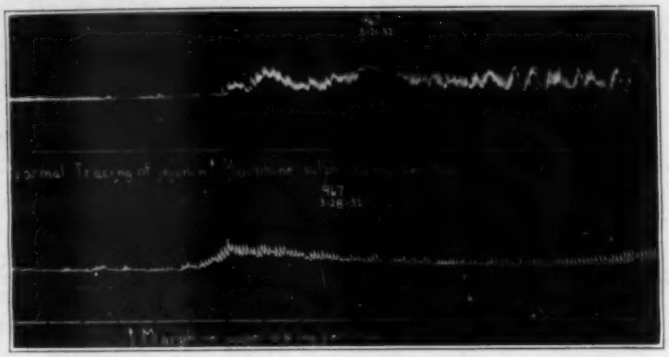

Fig. 3.—Obstruction of jejunum. Tracing made from Thiry-Vella loop independent of obstruction. Records made after the administration of morphine hypodermically one and seven days after obstruction.

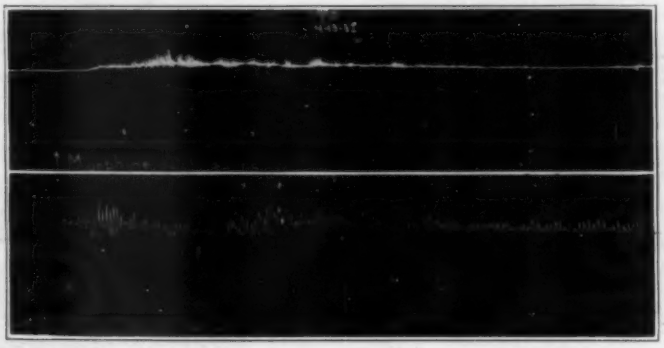

Fig. 4.—Obstruction of jejunum. Tracing of jejunum made just above the obstruction through an Ivy-Mann enterostomy. Records made one and six days after obstruction.

Ivy-Mann enterostomies in which the upper jejunum had been obstructed produced the same effect on the intestinal movements as that shown in normal animals (figs. 3 and 4). There did not seem to be any decrease or increase in the response as death approached.

As controls and for comparison, tracings of the jejunum were made after the administration of codeine sulphate, strychnine sulphate and

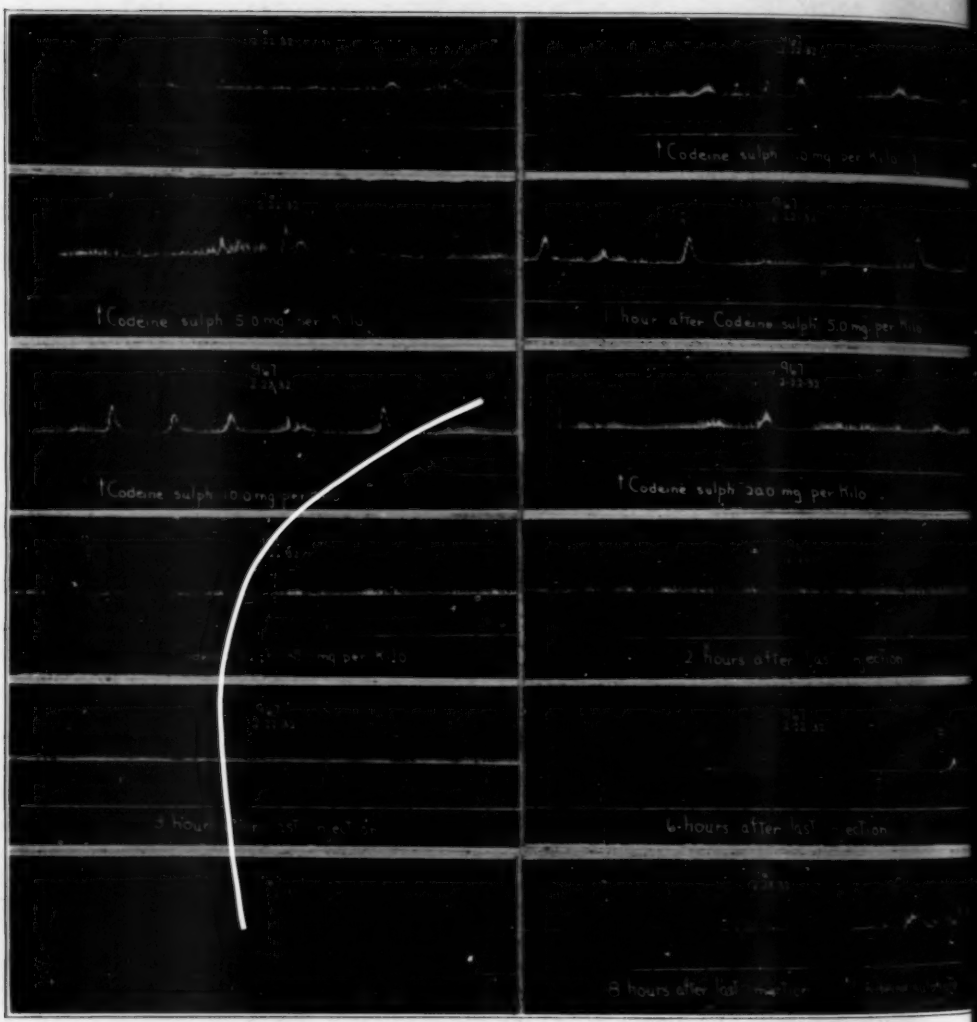
Codeine sulph 5.0 mg per Kilo
1 hour after Codeine sulph 5.0 mg per Kilo
Codeine sulph 20.0 mg per Kilo
2 hours after
6 hours after
8 hours after

Fig. 5.—Kymographic tracings of jejunum from Thiry-Vella loop. Codeine sulphate was given hypodermically in gradually increasing doses. Note the decrease in peristalsis after large doses. The rhythmic contractions continue as long as the effect of codeine lasts. Eighteen hours after the last large dose of codeine the intestine was again stimulated by a small dose.

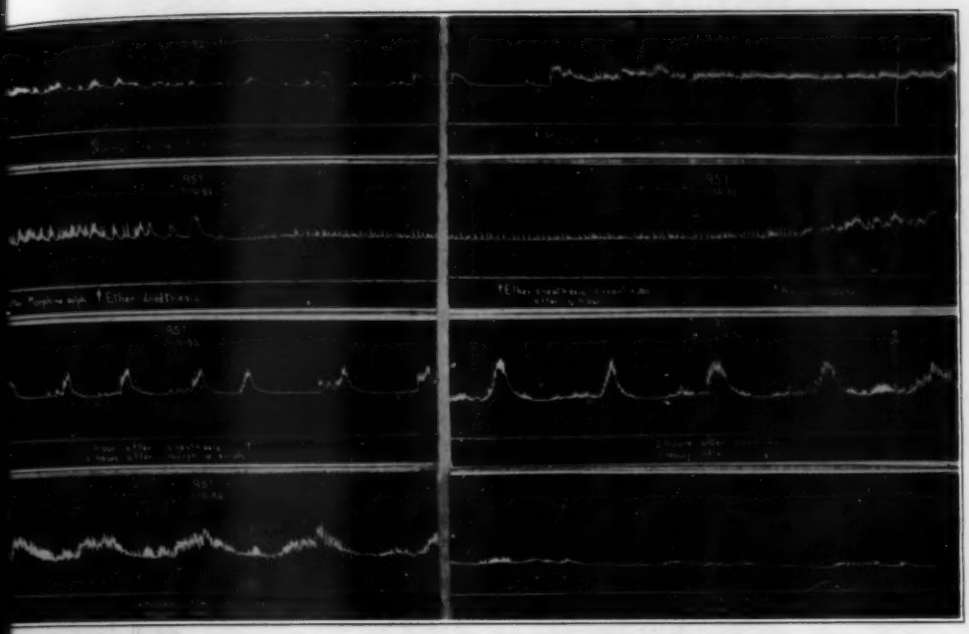

Fig. 6.—Tracing of jejunum from Thiry-Vella loop, showing effect of ether anesthesia after intestine has been stimulated with morphine. The effect of the morphine persists longer than the ect of ether.

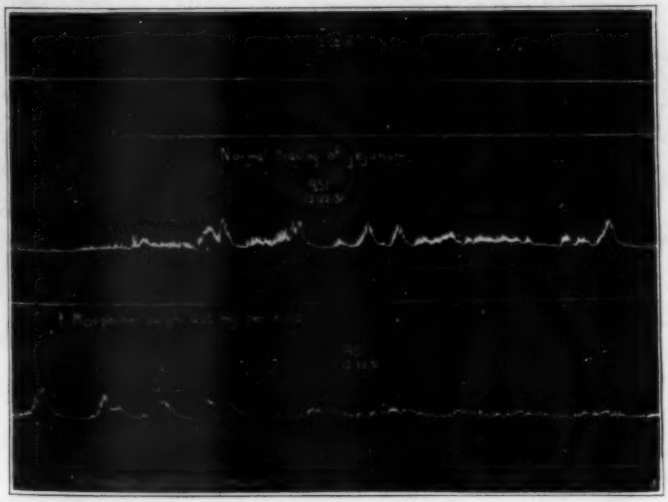

Fig. 7.—Kymographic tracing of jejunum from Thiry-Vella loop, showing the depressing effect of atropine after the intestine is stimulated with morphine.

atropine sulphate by hypodermic injection and of ether by inhalation (figs. 5, 6, 7 and 8).

In a patient on whom ileostomy had been performed, morphine in doses of from 1/6 to 1/2 grain (0.01 to 0.03 Gm.) increased the size and frequency of the intestinal movements. Auscultation showed great activity of the intestine, and the increased effect after morphine could also be observed directly on the protruding intestine at the site of the enterostomy. Certainly auscultation and the appearance of the intestine were just as striking as in the dog. Auscultation of four normal abdomens, of one case of intestinal obstruction, of four cases of severe generalized peritonitis and of two cases of uncomplicated paralytic ileus showed a marked increase in intestinal noises after the

Fig. 8.—Kymographic tracing of jejunum from Thiry-Vella loop, showing the absence of effect of strychnine sulphate given by hypodermic injection. There was no appreciable response after a dose sufficient to produce convulsions.

usual administration of 1/4 grain (0.016 Gm.) of morphine. Further studies of intestinal peristalsis in patients were made by observations of three with large hernias. Increased peristalsis was striking in all of these patients following the hypodermic injection of 1/4 grain of morphine.

Effect of Morphine on the Sphincters.—A dog that was free from intestinal parasites was given a barium meal of 100 cc., and the normal emptying time of the stomach was determined. The following three days the dog was given a subcutaneous injection of morphine, 0.5 mg. per kilogram of body weight, and fifteen minutes after each dose a barium meal was given. The normal emptying time of the stomach

was found to be two hours. After the administration of morphine, a marked retention was present after two hours. Emptying occurred in four hours.

Twenty cubic centimeters of thick barium was introduced into a dog on which ileostomy had been performed, and the normal emptying time of the ileum was determined. The following day an injection of 0.5 mg. of morphine sulphate was given before the injection of barium. Normal emptying of the ileum was found to be complete in two hours. After the administration of morphine, all of the barium remained in the ileum at the end of two hours.

A patient who had a normal emptying time of the stomach was also given ¼ grain of morphine followed by a barium meal. There was marked retention six hours after the administration of morphine.

SUMMARY

1. The effect of morphine sulphate on the movements of the jejunum in dogs was studied by means of kymographic tracings taken with a balloon in Thiry-Vella loops, through Ivy-Mann enterostomies of the upper jejunum, and of the ileum through an ileostomy. The effect of morphine on the normal and obstructed small intestine was also studied.

2. The effect of morphine on the movements of the small intestine in human beings was studied by means of tracings taken with a balloon through an ileostomy opening, by observations of large hernias and by auscultation of both the normal and the pathologic abdomen.

3. The effect of morphine on the sphincters of the intestine in dogs and in man was studied by means of the x-rays.

4. Morphine sulphate in ordinary doses gives an increase in tone, an increase in the amplitude of segmentation movements and an increase in the frequency and amplitude of peristaltic waves. Large doses stop peristalsis and decrease the tone, but segmentation movements are little affected and may be somewhat increased. The duration of the effect of an average dose of morphine on the intestine is about six hours. This is true for both animals and man.

5. Morphine stimulates the obstructed intestine as well as the unobstructed intestine in animals as recorded by the kymograph, and in man and animals as determined by auscultation. There appears to be no increase or decrease in response to morphine as death approaches.

6. A single dose of morphine caused retention of the barium meal in the animal and in the human stomach. The emptying time was at least twice the normal. A marked delay in the emptying of the ileum in the dog was noted. Morphine evidently produces a spastic action on the sphincters which delays the progress of barium through the gastrointestinal tract.

CANCERPHOBIA

SPECIAL RELATION TO INSIGNIFICANT AND FANCIED LESIONS OF THE TONGUE

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The purpose of this communication is to call attention to the increasing frequency of cancerphobia, especially as seen in patients with minor complaints referable to the tongue.

Cancer propaganda has greatly increased the number of people who present themselves to the physician regarding a benign or early new growth. However desirable this state of affairs may be, it has added considerably to the difficulties and responsibilities of the medical profession. More than ever, clinicians must be alert to make a correct diagnosis in patients who may present little in the way of signs and symptoms. A small neoplasm often intrudes so slightly on the organism that its detection may call for the greatest diagnostic acumen. MacFee [1] has recently pointed out that a number of examiners fail to discover lingual carcinomas before they have progressed to an advanced stage. On the other hand, the patient may not have an organic disease, but to arrive at such a decision may be exceedingly difficult. Thus, one may be puzzled as to the absence or presence of an organic disorder, and, when the latter has been established, its malignancy or benignancy may furnish a perplexing problem.

After the malady has been correctly evaluated, proper treatment assumes paramount importance. Sometimes it is no easy matter to convince the patient that his ailment is unrelated to cancer. When a benign tumor is disclosed, the mere fact that objective treatment is instituted may serve to reassure the patient; but, if no physical abnormality is revealed and nothing is done, the fears of the patient may be increased to such an extent that they may be dispelled only by a high degree of sympathy, understanding, and patience on the part of the physician. In some instances simple reassurance from the medical attendant will permanently and wholly allay the person's anxiety. In many other cases a careful, detailed explanation must be given to the patient in order

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1. MacFee, W. F.: Concealed Cancer of Tongue, Ann. Surg. **93**:481, 1931.

to convince him that he is not afflicted with cancer. In a busy clinic it often happens that insufficient time is devoted to this task, and the patient departs with such mental anguish that he forsakes his work and enters on a vicious circle of medical shopping. Thus industrial and economic problems may be introduced as well as a reduplication of effort on the part of various physicians and medical organizations. Therefore, it devolves on those who first examine these sufferers to do all that is possible for their peace of mind and to inaugurate whatever is indicated in the way of treatment, even though the latter may be simple and designed for psychic effect. Experience teaches that the response on the part of the patient amply justifies any special attention that may be given to his problem. Indeed, there are few, if any, fields in medicine where the physician may better practice the art of his profession.

Apparently, neither Ewing [2] nor Roussy [3] has emphasized the recent increase of cancerphobia. Rose [4] and Marshall [5] have briefly noted the occurrence of cancerphobia in relation to hypersensitiveness and hypertrophy of the lingual foliate papillae. Fitzwilliams [6] has mentioned the same condition. In some of the patients on whom the present study is based the complaints were analogous to those described by the three aforementioned authors, but in others the setting was entirely different.

Zagni [7] and a few others have called attention to glossal papillomas, but their patients consulted the physician because of the increase in the size of the lesion and not on account of any morbid fears connected with the ailment. In such an instance, the objective findings were of main interest, whereas in the present group the subjective features were of paramount importance.

In our cases, even the immediate exciting cause for the hypersensitiveness was sometimes obscure. Occasionally, an ill-fitting dental plate or a rough tooth irritated the area. Not infrequently, the foliate papillae were slightly or moderately enlarged (fig. 1). In some instances no abnormality could be detected.

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2. Ewing, J.: Neoplastic Diseases, ed. 3, Philadelphia, W. B. Saunders Company, 1928.

3. Roussy, G.: Le Cancer, in Roger, C. H., et al.: Nouveau traité de médecin, ed. 2, Paris, Masson & Cie, 1929, vol. 2, part 5.

4. Rose, B. T.: A Note on the Hypertrophy of the Papilla Foliata in Man, Lancet **2**:14, 1927.

5. Marshall, C. J.: The Papillae Foliatae and Carcinophobia, Brit. M. J. **2**:13, 1928.

6. Fitzwilliams, D. C. L.: The Tongue and Its Diseases, London, H. Milford, 1927.

7. Zagni, L.: Papilloma della lingua, Riforma med. **42**:871, 1926.

The women outnumbered the men and were usually of a very nervous temperament.

STATISTICAL STUDIES

Since no adequate data were available concerning patients who had been turned away with the diagnosis of "no significant lesion" and whose complaint was merely slight pain or sensitiveness, it seemed worth while to scrutinize the records of patients when the clinical diagnosis of a common, benign lesion of the tongue had been confirmed by microscopic studies. It seemed that if such a pathologic process represented the worst type of benign lesion, so far as the later development of cancer might be concerned, disorders of lesser note should entail fewer chances of subsequent malignant changes taking place.

In this connection, Fitzwilliams [6] stated that papilloma is the "commonest simple tumor of the tongue," and when it appears in middle life he regards it with distinct suspicion. Ewing [2] stated that in papillomas of the tongue "there is a strong tendency toward malignant change," and that "a large proportion of lingual carcinomas exhibits a brief preliminary papillomatous stage." Thus it would seem that a review of distinctly suggestive papillomas of the tongue might yield some information concerning the likelihood of a carcinoma becoming engrafted on a benign lingual lesion.

By studying the laboratory records in the department of pathology, the following facts were disclosed. From 1918 to 1923, inclusive, biopsies were performed on nine glossal papillomas, and from 1924 to 1928, inclusive, thirty-one similar diagnoses were recorded. The total number of forty cases for the eleven-year period was surprisingly small, but the distinct upward increase for the past few years was well indicated. In only twenty-three of the aforementioned records were there sufficient data to warrant their being used, and in eight of these cases the condition was sooner or later histologically diagnosed as carcinoma.

This left a group of fifteen cases in which (during the period of observation) the lesion remained unquestionably benign. Six of these patients were women. The average age for both sexes was 50 years; the patients were thus within the period when Fitzwilliams [6] would regard all papillomas of the tongue with suspicion. Most of the complaints were pain or "irritation" of the affected region. Only one patient had a positive Wassermann reaction. Bad teeth and poorly fitting dentures were usually found.

From the foregoing small amount of evidence one may surmise that even when the papillomas were so atypical that cancer could not be

ruled out of the clinical diagnosis, carcinoma never developed in 66 per cent of the patients within the observation period. From such facts one may deduce that lesions of much less significance than papillomas, as exemplified by sensitive areas or a simple hypertrophy of the mucous membrane, will be far less likely to give rise to cancer, therefore the patient should be completely reassured with the hope that all of his fears may be adequately dispelled.

Naturally, the aforementioned opinion does not hold for the 35 per cent of the patients who did have a malignant process. They are in an entirely different category, and should have proper, intensive, objective treatment with much less relative emphasis being placed on psychotherapy or symptomatic measures.

Fig. 1.—Posteriorly, along the left border of the tongue, were some enlarged foliate papillae. A similar condition existed on the right side. The remaining upper teeth may be seen. This photograph was taken during the patient's first visit to the hospital.

CLINICAL STUDIES

Perhaps the signs and symptoms presented by many patients who have cancerphobia due to a fancied or benign lesion of the tongue may be demonstrated best by two case histories, each fairly typical of certain members of the group.

REPORT OF CASES

CASE 1.—*History.*—M. K., a white woman, aged 50, married, complained of having a lingual "cancer." Four months before coming to the hospital she had noticed a laceration on the left side of the tongue and had attributed it to the impingement of a tooth. During this time she had pain in the lumbar region and consulted a physician, who recommended the extraction of certain teeth. She complied, but obtained no relief from the rachiodynia. Following this a sensation of "roughness" developed in the foliate papillae, and a "sore" spot appeared on the

end of her tongue. One week before presenting herself at the clinic, her physician advised her coming to the hospital, saying that she "might have a bad disease." Her husband then forbade her to prepare his food, and added to her fears by telling her that she had a cancer and would have her tongue taken out. When an acquaintance supported her husband's dire predictions, she hastened to the hospital. The past history and family history seemed irrelevant.

Physical Examination.—The patient was well developed, slightly obese and extremely apprehensive. She appeared to be in good physical condition, and presented no defects aside from those to be set forth. The tongue was of normal size, shape, color and consistency. Its tip was hypersensitive. The foliate papillae on each side were moderately hypertrophied and slightly tender (fig. 1). The buccal mucous membrane appeared normal. She had a few lower and upper teeth, all of which were carious and loose. Gingivitis was marked.

Treatment.—The patient was advised to eat nothing but bland foods, to have several of the remaining teeth extracted, and to return within two weeks, or sooner

Fig. 2.—This picture depicts the same patient as in figure 1, and was taken eighteen months later. By comparison it will be seen that four of the upper teeth have been removed, and that the foliate papillae have become slightly flattened.

if she wished. She was told positively that she did not have cancer and need not have the slightest worry about that. She departed in a happy frame of mind.

Course.—The patient was followed up at fortnightly intervals. Her anxiety reappeared several times, but it became increasingly easier to dispel, and finally she became thoroughly convinced that she was not suffering from cancer. When she was last seen (one and one-half years later), she had only slightly less enlargement and tenderness of the foliate papillae (fig. 2) and fewer teeth than when she first came under observation; her complaint was one of financial difficulties without reference to any physical ailment.

This case illustrates the type of lesion that is perhaps most often associated with cancerphobia of the tongue. Hypersensitivity and enlargement of the foliate papillae are not dangerous in themselves, but their annoyance to the patient and the usual inattention given to the psychic side of the case by the physician lends to them an exaggerated importance. In some instances it may be necessary for the mental, as

well as the physical, relief of the patient to remove or destroy the offending area.

CASE 2.—*History.*—M. W., a white woman, aged 68, married, complained of xerostomia and tenderness of the tongue which had been present for the past seven months. She was afraid that she had a lingual "cancer." Her malady had been progressive. Various mouth washes prescribed by physicians had seemed to increase the abnormal sensitivity, and recently the throat had become involved. Of late, the glossal tenderness had increased so that she could scarcely eat, and her sleep was disturbed by sharp, sticking sensations throughout the tongue, the tip of which rested against an upper dental plate. She was convinced that she had cancer and that little, if anything, could be done to alleviate her condition. Her habits, including those of drinking and eating, had been normal. During the past eight years she had unaccountably lost 15 pounds (6.8 Kg.) in weight. Thirty-four years previously she had "neuritis" in both upper members, which disappeared after "injections in the arms." She had had an upper dental plate for the past twenty years and a lower denture for five years. At 65 years of age, her father died of "dropsy and rheumatism," and her mother succumbed to tuberculosis in her twenty-fifth year. The marital history was irrelevant.

Physical Examination.—The patient was well developed and moderately well nourished. Her extreme anxiety was apparent. She had 6 lower teeth, 2 of which had gold crowns. The left lower canine was eroded at the gum margin. The dental plates appeared to fit satisfactorily. The openings of the submaxillary salivary gland ducts were elevated and dilated. The entire buccal and pharyngeal mucous membrane was moderately hypersensitive and slightly redder than normal. The tongue was of normal size, shape and consistency; its tip was erythematous, except for a tender yellow area, 2 mm. in diameter and 1 mm. in height. There was moderate hypertrophy of the circumvallate and fungiform papillae, and the lymphoid tissue at the base of the tongue seemed more abundant than normal.

Laboratory Observations.—The Wassermann reaction of the blood was negative. The gastric contents during fasting contained no free hydrochloric acid but had a total acid of 8 per cent; thirty minutes after eating two slices of white bread the free hydrochloric acid was zero, and the total acid was 10 per cent. Urinalysis gave negative results, except for many white blood cells and a hyaline cast in the centrifugated sediment. Chemical analysis of the blood showed: blood sugar, 133 mg., and blood urea, 7.4 mg. per hundred cubic centimeters of blood. Smears from the tongue, mouth and pharynx were stained with carbol fuchsin and revealed many variously arranged cocci in large epithelial cells, a few bacilli and a moderate number of white blood cells. Examination of the blood disclosed: hemoglobin, 80 per cent; red blood cells, 3,720,000, and white blood cells, 4,000; a differential count showed 50 per cent polymorphonuclear neutrophilic leukocytes, 18 per cent large lymphocytes and 32 per cent small lymphocytes. The shape and size of the red blood cells were normal. No explanation was discovered for the slight anemia.

Treatment and Course.—The patient was told that she certainly did not have cancer, and her immediate relief was gratifying. No medications were allowed. She was directed to eat bland foods and was given a list from which to select them. She was instructed to keep an accurate dietary record and to bring it to the hospital at each weekly visit.

For a few months the patient improved rapidly, and most of the symptoms disappeared. She was last heard from two and a half years after her first visit to the clinic. She still had complaints concerning her tongue, mouth and throat, and considered that she was in poor health, but she did not have any fear concerning cancer.

This case exemplifies a condition in which the objective findings are slight, but the subjective features are pronounced. Despite the failure to relieve the patient of her symptoms more than temporarily, she had no recurrences of the cancerphobia, which was the primary cause of her presenting herself at the clinic. The case is reported from that standpoint, and not from that of giving the patient relief from the

Fig. 3.—The tongue was removed in toto at autopsy and fixed in a 10 per cent solution of formaldehyde. The photograph illustrates where the sections were taken for histologic study.

underlying disease.[8] One should essay the latter, and careful inquiry should be made into the cause of the xerostomia and stomatodynia in order to remove or lessen the fundamental pathologic condition. The emotional side must be closely studied, for it is often the key to the situation. However, physical defects should be carefully searched for, as they may constitute the exciting, if not the underlying, derangement, and their elimination may effect a cure or betterment.

8. An extended absence followed by the acceptance of a post in another city nullified the author's intention to attempt this accomplishment.

HISTOLOGIC STUDIES

It is common knowledge that, in addition to its special functions of speech and taste, the tongue is one of the most sensitive parts of the body. In patients suffering from cancerphobia in relation to the tongue, hyperesthesia is a prominent feature, and in some cases this is associated with annoying disturbances in taste. Biopsy usually shows surprisingly little to account for the symptoms. On the other hand, one may see gross lesions of various degrees and types which give little or no concern to the patient because no unpleasant sensations are connected with them.

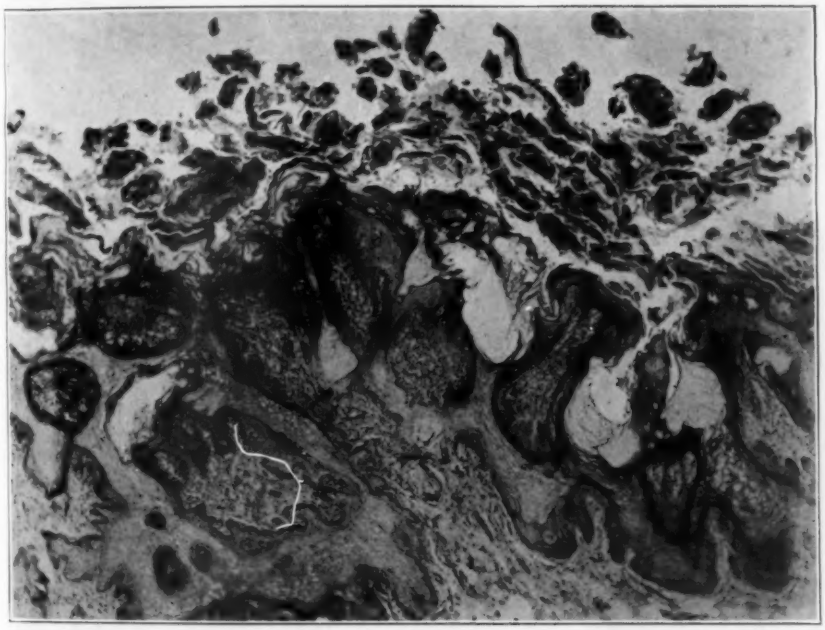

Fig. 4.—Beyond the hornified epithelium covering the tongue there was a considerable collection of inspissated mucus, masses of bacteria and partially disintegrated cellular material (× 55). There were no lingual symptoms.

In a study of autopsy material, sections were taken from four regions of one hundred tongues (fig. 3). Not infrequently microscopic lesions could be demonstrated which were far greater than those in patients afflicted with cancerphobia resulting from paresthesias, tiny ulcers, slight hypertrophy of the mucous membrane or mild gustatory derangements. In none of the patients on whom necropsy was performed had there been any complaints referable to the tongue, and they had died from diseases which had no connection with the mouth, throat or nose. It was hoped that such a study might give some clue to the

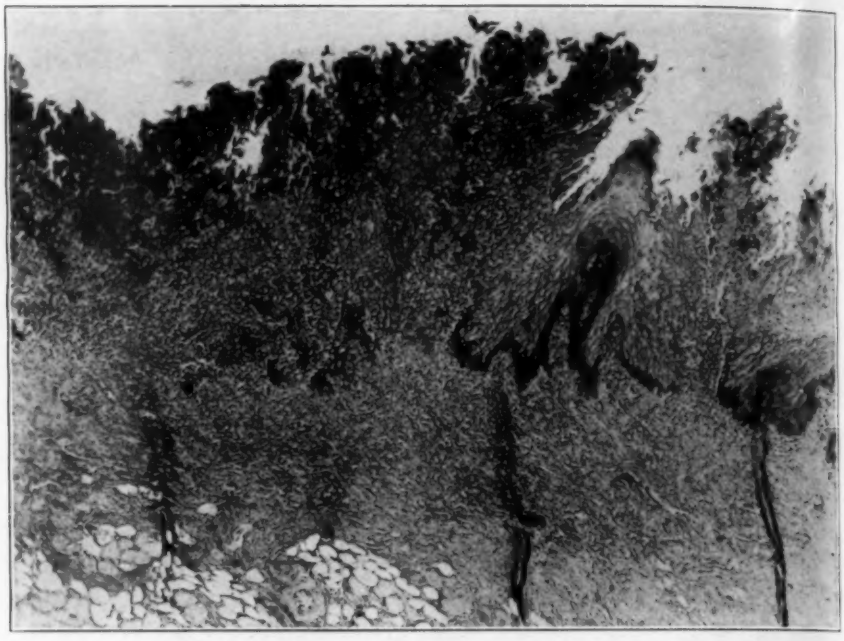

Fig. 5.—This photomicrograph reveals marked necrosis and suppuration of the lingual mucosa and adjacent, underlying tissue (× 72). The patient had no symptoms referable to the tongue.

Fig. 6.—In the lower central portion of the photomicrograph (× 72), there may be seen a distinct loss of the epithelium without any associated infection. The patient had no complaints concerning his tongue.

amount of damage which the tongue may sustain without the person being aware of it.

The amount of microscopic débris that collected on the surface of a normal-appearing tongue was astonishingly great. When sordes was clinically present, this accumulation became enormous. In both instances there was a mixture of cast-off epithelium, food, bacteria and mucus (fig. 4).

Fig. 7.—This photomicrograph (× 30) depicts a glossal papilla in the process of extrusion. Sufficient hypertrophy of such a structure could lead to the formation of a true papilloma. The tongue from which this section was taken was normal.

Erosions of the mucous membrane were not uncommon, and occasionally the associated infection was considerable (fig. 5), while in some it was entirely absent (fig. 6). In other areas the epithelium was hyperkeratotic but well preserved. Many papillae were hypertrophied, and varying degrees of extrusion were seen (fig. 7).

Numerous nerves were observed in the submucosal tissue, but no lesions were revealed with the use of hematoxylin and eosin stain. The mucous glands, with their ducts, were normal and abundant. The muscle and connective tissue revealed no pathologic process. In the posterior portion of the tongue the lymphoid tissue was bulky and covered by thin squamous epithelium.

COMMENT

Determination of the cause and treatment of cancerphobia are not usually simple matters. The malady is sometimes the result of an easily recognized organic lesion which can be eradicated. In other instances the underlying physical factor may be so obscure as to tax the powers of the most ingenious diagnostician and to place him in a very difficult situation, for he must properly evaluate the condition before intelligent treatment may be instituted. Therefore, the greatest problem is encountered in patients who have an insignificant or a fancied lesion. An underlying cause must be ferreted out and therapy directed toward that cause. One cannot overemphasize the need for taking the complaints of the patient seriously, and effectively aiding him, lest he become a victim of morbid fear and a burden to those about him.

It is a fact that the malignancy or benignancy of practically all demonstrable lesions of the tongue can be correctly diagnosed by a capable, experienced physician, especially if he resorts to laboratory aids and clinical consultations. Hence, when one is sure that the lesion is not cancer, it is wise to assert such a conviction in order that the patient may receive the benefit of a wholehearted assurance.

The tongue is supposedly a common site for papillomas. In fact, the normal papillae are miniature forms of such a structure, and therefore their enlargement readily results in a true papillary tumor. And yet, from the statistical data at our disposal, it has been indicated that true lingual papillomas are rarely encountered in the pathologic material of the hospital. From this it may be assumed that most people who have had ordinary papillomas of the tongue have not found their way into a hospital for patients with cancer but have been cared for by other medical agencies. It is difficult to ascertain in how many of these a malignant process developed. However (in this series), of the patients who have had papillomas of the tongue so distinctly suggestive that carcinoma could not be ruled out of the clinical diagnosis, 65 per cent did not have cancer within the period of observation. The other 35 per cent probably included a goodly number of patients with papillary carcinomas, but the original biopsy was too superficial to give the true picture. It would seem, then, that the ordinary benign glossal papilloma could be easily and safely removed, and that the clinical findings supported

by a histologic diagnosis would justify the physician in making positive statements in order to allay any associated cancerphobia. Again, it might be emphasized that one should know his ground, but, knowing it, should not be afraid to tread on it.

Cancerphobia attendant on a simple hypertrophy of the foliate papillae which does not reach the stage of a true papilloma may ordinarily be effectively dealt with by some method other than extirpation or destruction in situ, but the latter procedures may be performed with good results, thereby removing an objective feature.

Hypersensitivity and pain may be associated with xerostomia and no cause found for either. Usually such a condition is hard to cope with and will call for patient, long-continued, intelligent treatment. If no physical basis can be found, a close study of psychic factors may reveal the key to the situation.

In the light of newer knowledge concerning the participation of the sympathetic nervous system in the phenomena of pain, it should be exceedingly interesting to induce a temporary block with procaine hydrochloride and to witness the effect, if any, that would be produced on the patient's symptoms. If success were obtained, it would then be feasible to inject alcohol into the sympathetic ganglions or to extirpate them. Moreover, one might try blocking the sensory nerves to the area if the interruption of purely sympathetic pathways gave no relief.

The fact that people have gross and microscopic lesions of the tongue without disturbances in sensation is further evidence that nervous or psychic disorders rather than organic ones constitute the essential derangement in cancerphobia.

The tongue is subject to continuous trauma and infection. The amount of cellular and other débris is enormous, and at times even whole papillae are cast off. The nerve supply is unusually abundant. The prominence of the organ and consequent easy manner of viewing it, the use of it as an index of general health, its special functions connected with speech and taste, and its high degree of sensitivity all tend to focus the patient's attention on his tongue. These facts, added to the layman's knowledge of the terrible mutilation and high mortality attendant on a glossectomy coupled with his great fear of cancer in any form or region, are sufficient to strike terror into the stoutest heart. It is small wonder, then, that a person of nervous or emotional instability cowers before the possibility of such a scourge and becomes an easy victim of cancerphobia. Such unfortunates present excellent opportunities for the practice of medical art and humanitarianism.

SUMMARY

Attention has been called to the increasing number of patients with benign new growths who present themselves. Emphasis has been placed

on those who have developed cancerphobia as a result of an insignificant or fancied lesion of the tongue. Stress has been placed on the responsibility of the physician to make a correct diagnosis as to the existence or nonexistence of a malignant tumor and, in the latter instance, to give special time and thought to dispelling the fears of those who may be suffering from cancerphobia.

Since insufficient, or no, data were recorded in cases in which there was a tiny lesion of the tongue or none, there has been included a short statistical study of lingual papillomas, since they are the commonest in the group of benign tumors of the tongue and are, at the same time, most liable to undergo malignant changes. In the present series, 65 per cent of distinctly suggestive glossal papillomas remained benign throughout their observed course.

As a matter of illustrating signs and symptoms together with a simple form of treatment, the histories of two cases were included. One patient complained of undue sensitivity in the lingual papillae on both sides of the tongue, and the subjective features were eliminated by simple psychotherapy combined with oral hygiene. The other cancerphobist had xerostomia associated with paresthesias of the buccal and pharyngeal mucous membranes, the symptoms being most pronounced over the anterior portion of the tongue. It was possible to reduce temporarily the abnormal sensations and to dispel permanently the patient's fears of having cancer.

In order to obtain histologic data concerning the existence of lesions without associated sensory disturbances, a series of one hundred tongues secured at autopsy was studied. Enlarged papillae, erosions of the mucous membrane, superficial infections and collections of débris were often found. Since no patient had had complaints referable to the tongue, it was assumed that under suitable conditions such lesions as those described may exist without being noticed by the patient.

CONCLUSIONS

1. Cancerphobia is apparently on the increase. It should be actively combated by sagacious, patient, sympathetic treatment.

2. Many patients suffering from a morbid fear of lingual cancer have no demonstrable lesion; others have a benign one which is often a simple hypertrophy of the foliate papillae.

3. An analysis of twenty-three cases of lingual papillomas in which malignancy was suspected or could not be ruled out clinically revealed that during the period of observation 65 per cent of the patients did not show carcinomatous changes. From this it is reasoned that patients suffering from far more insignificant, or from fancied, lesions of the tongue have little to fear in the way of these becoming cancerous.

4. A microscopic study of one hundred tongues taken at autopsy demonstrates that patients may have small lesions of this organ without sensory disturbances. This supports the idea that cancerphobia is the resultant of underlying psychic and nervous disorders rather than a fundamental physical derangement.

Since writing this paper, I have found an article entitled "L'organe folié de la langue, cause possible d'un diagnostic erroné de cancer," by A. Lacassagne (Radiophys. et radiothérapie **2**:131, 1930) which apparently has a direct bearing on the subject of "Cancerphobia."

PROGNOSIS IN CARCINOMA OF THE STOMACH

REMOTE RESULTS OF SURGICAL TREATMENT TO JANUARY, 1930

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AND
JOHN W. KLOPP, M.D.
PHILADELPHIA

The literature on carcinoma of the stomach is so voluminous that writers should refrain from adding to the confusion unless they follow some uniform plan of record, such as that proposed by Greenough and Simmons.[1] In analyzing our cases we lay no claim to special success in securing what are apparently a few cures, but present even such modest results as a challenge to a disease which unmolested always carries the patient to his grave with absolute certainty. If it could be shown, for instance, that a patient with cancer of the stomach may live untreated for five years, then our conclusions regarding the efficacy of surgical eradication would be unsound. But lacking such proof, we must rely on the surgical method as the only successful means of treatment.[2]

The stomach is the most common site of human cancer (fig. 1[3]). The statistics from which the diagram in figure 2 was drawn show

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Read in abstract at a meeting of the College of Physicians of Philadelphia, May 4, 1932.

† Dr. Ashhurst died Sept. 19, 1932.

1. Greenough, R. B., and Simmons, C. C.: Boston M. & S. J. **185**:253, 1921.

2. We are aware that isolated instances of patients surviving over five years with untreated carcinoma are on record, but not, as far as we know, of gastric carcinoma. Dr. Peter P. Klopp recalls a woman with unmistakable clinical cancer of the left breast in the days before the therapeutic use of radiant energy, who refused treatment, but who nevertheless lived for eighteen years after the diagnosis was made. The longest period of survival in surgically untreated cancer of the stomach that we were able to find in the literature is three years. ((*a*) Bloodgood, J. C.: Ultimate Results and Actual Functional Results After the Different Types of Operations After Intervals of Five Years or More, Ann. Surg. **92**:574 [Oct.] 1930; (*b*) Hitzenberger, K., and Merkler, D.: Cancer of the Stomach: Fate of Patients Treated at First Medical Clinic, University of Vienna, Wien. klin. Wchnschr. **44**: 632 [May 15] 1931.)

3. The figures from which this drawing was made represent the death rate per hundred thousand, and not the incidence of cancer. According to the medical department of the Metropolitan Life Insurance Company, there are no reliable statistics for the incidence of cancer of the stomach, the best available figures on deaths probably being those furnished by the Annual Reports of Mortality Statistics published by the United States Bureau of the Census (personal communication). However, since the death rate and incidence are so nearly alike, the figure given portrays incidence accurately enough.

that there is an unmistakably significant trend toward an increase in the incidence of this disease, especially among males, who are apparently afflicted more frequently than females, the difference between the sexes widening with the passage of years. Caucasians suffer more often than blacks (fig. 3), and economic station has some bearing, for the more prosperous group seem to suffer less frequently (fig. 2). The age incidence of carcinoma of the stomach in a vast series of cases is shown in figure 3. Our own figures, which follow, show that most of fifty-four patients were in the sixth (eighteen) and seventh (eighteen)

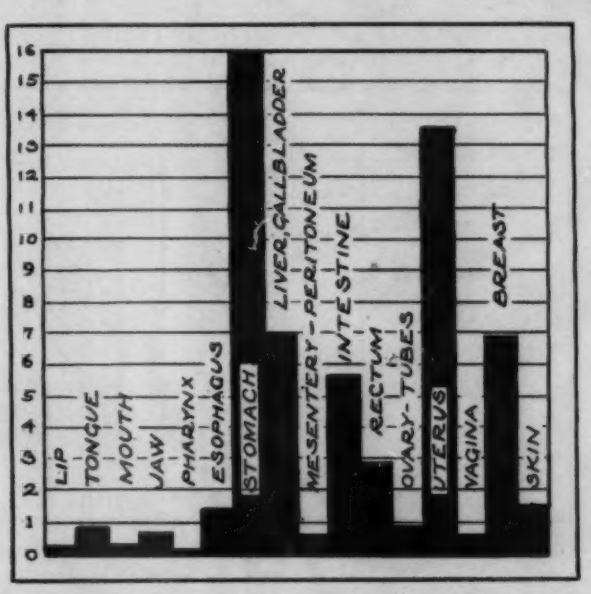

Fig. 1.—Diagram drawn from statistics of the Metropolitan Life Insurance Company, Industrial Department, 1922, showing that the stomach is the most common cite of cancer.[3]

decades of life at the time of treatment: third decade of life, two patients; fourth decade, four; fifth decade, eight; sixth decade, eighteen; seventh decade, eighteen; and eighth decade, four.

The significant feature about both sets of figures is the surprisingly high incidence in the young adult, a fact which belies the usual statement in textbooks. Our youngest patient was 27 years of age, the next youngest being 30 and 33 years, respectively. While the average age of patients in our own series at the time of treatment was about 56 years, more than 25 per cent of them were 50 years of age or less. Among the reports of cancer of the stomach in young patients are

those of Mintz's[4] 11 year old boy; Marble's[5] 17 year old girl; Morian;[6] Jones and Scott[7] (five year cure in a 24 year old man), and Nicholson.[8] Osler and McCrae[9] collected six reported cases in persons under the age of 10.

We observed more than twice as many men as women (thirty-eight male; sixteen female).

DIAGNOSIS OF CANCER OF THE STOMACH

Symptoms.—Patients with gastric carcinoma fall into three groups according to the type of clinical symptoms from which they suffer: (1) those with a short history (i. e., up to six months); (2) those with

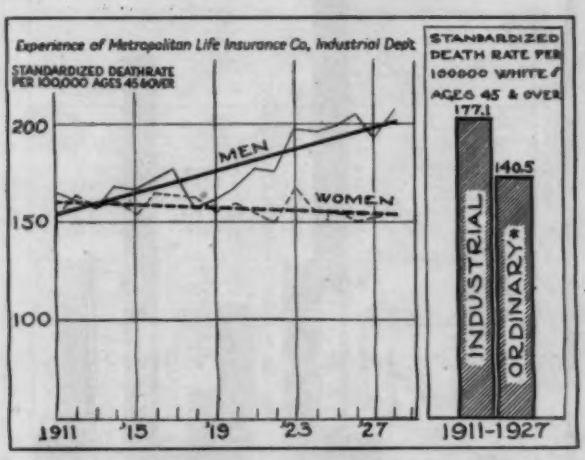

Fig. 2.—Diagram showing how cancer of the "stomach-liver" varies with time, sex and economic station. The star indicates the more prosperous group.

a long history (over six months), and (3) those with no history of the dyspepsia syndrome.[10]

4. Mintz, M. M.: Cancer of the Stomach in 11 Year Old Boy, Vestnik roentgen. i radiol. **8**:357, 1930.

5. Marble, A.: Cancer of Stomach in 17 Year Old Girl, Bull. Johns Hopkins Hosp. **48**:39 (Jan.) 1931.

6. Morian, R.: Cancer of the Stomach in Young Persons, Arch. f. klin. Chir. **164**:329, 1931.

7. Jones, E. B., and Scott, M.: Cancer of the Stomach: Case with Apparent Cure, M. J. Australia **1**:554 (April 26) 1930.

8. Nicholson, S. T.: Consideration of Certain Diagnostic Features of Cancer of the Stomach, Pennsylvania M. J. **34**:169 (Dec.) 1930.

9. Osler, W., and McCrae, T.: Cancer of the Stomach in the Young, New York M. J. **71**:581 (April 21) 1900.

10. Berger, W.: Cancer of the Stomach: Present Status of Early Diagnosis, Wien. klin. Wchnschr. **44**:33 (Jan. 9); 71 (Jan. 16); 108 (Jan. 23) 1931.

Group 1 comprises about from 50 to 60 per cent of all cases in our experience, a figure which agrees with those cited by Dwyer, Blackford and Turner,[11] and by Oberniedermayr and Stahnke.[12]

About 35 per cent of all cases fall into group 2.[10]

According to some authorities with significantly large series, group 3 is composed of from 2 per cent[10] to 18 per cent[11] of all cases. Our ward case 3899 is an example of one of these patients who had no complaint concerning his digestion or stomach, showing how difficult it is occasionally to make a correct diagnosis.

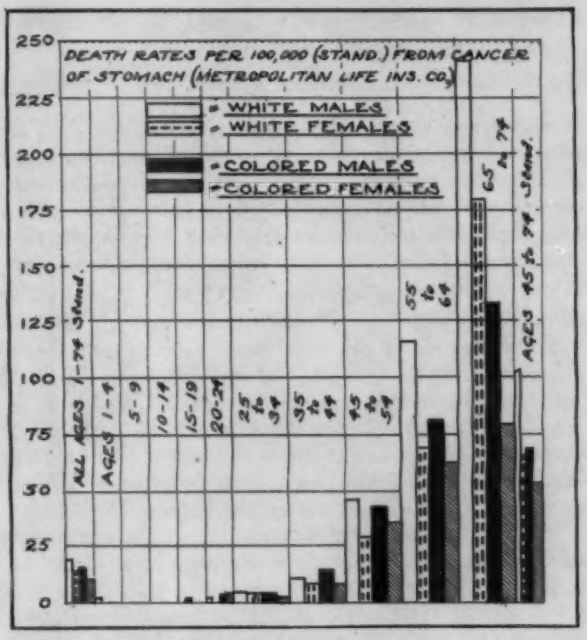

Fig. 3.—Diagram showing how cancer varies with color, sex and age periods.

Ward Case 3899.—A woman 33 years of age on Feb. 17, 1925, complained of pain in the lumbar region and the pelvis. The presence of carcinoma of the stomach was not even suspected. The patient was examined several times by Dr. Haines (cystoscopy) for ulcerative cystitis, and died a month after admission, of exhaustion and bedsores. Only at necropsy was carcinoma of the stomach (nonobstructive) found, with secondary carcinoma of the pancreas, the lungs and the ovary.

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11. Dwyer, M. F.; Blackford, J. M., and Turner, H. C.: Carcinoma of the Stomach: Clinical Study of 100 Cases, J. A. M. A. **93**:1456 (Nov. 9) 1929.

12. Oberniedermayr, A., and Stahnke, E.: Carcinoma of the Stomach: Surgical Treatment, 1922-1926, Koenig's Clinic, Deutsche Ztschr. f. Chir. **214**:387. 1929.

At first, most of the patients complain of indigestion and lack of appetite, especially for flesh, and loss of strength and weight, rather than actual pain. Later, most of them experience pain, usually in the epigastrium, but not necessarily so, and this occasionally radiates to the lumbar or shoulder region or into the pelvis. The coexistence of epigastric tenderness is common. The prominence of vomiting depends on whether or not there is pyloric obstruction. Those patients in group 3 (without the dyspepsia syndrome) often suffer from weakness and anemia, cardiac disturbances, fever and sweating, or from neuralgia (bone metastasis). The peculiar lemon tint of the skin of anemic patients is said to be characteristic of gastric cancer. The difficulty of diagnosis based solely upon symptomatology is illustrated by the following four cases.

A woman, 48 years of age, who had been under the care of an able neurologist for six months, with the diagnosis of neurasthenia, was found (by exploratory laparotomy, 1925), when a surgeon's advice was finally sought because of failing strength, anorexia and abdominal discomfort, to have an operable mass of carcinoma at the pylorus. Gastrojejunostomy brought symptomatic relief, maintained until the patient's death four months later from lobar pneumonia.

A man of 79 years had lost 42 pounds (19.1 Kg.) during the preceding two years; for eighteen months his stomach had troubled him, his chief complaint being pain there from three to four hours after meals, relieved by taking food. This is considered fairly characteristic of ulcer of the duodenum. Exploration (1919) showed a fixed, but not entirely immovable, mass on the posterior wall of the stomach, much nearer the cardia than the pylorus, causing hour-glass deformity. Gastrogastrostomy (at Walter Reed General Hospital March 14, 1919) brought the patient immediate relief, which was maintained for eighteen months. Secondary nodules became palpable in the liver, and on one occasion the patient vomited some of the tumor, which was shown under the microscope to be adenocarcinoma. Death occurred nine months after operation following a terminal illness of three weeks.

Another man, 52 years old (Jan. 28, 1916), had been under treatment in the medical ward, and (just four weeks after he had been dismissed as "cured" of "ulcer of the stomach") was readmitted to the surgical service with an inoperable carcinoma. This patient, whose gastric symptoms extended over a period of two years, was also relieved by gastrojejunostomy (January, 1916) and returned to his work as a farmer, plowing and reaping all summer; in September he came back with carcinomatous nodules in the otherwise empty sac of an inguinal hernia; he continued to be comfortable so far as his digestion was concerned, until January, 1917, and died in February, thirteen months after operation.

Another patient, a woman, a lawyer, 39 years old (1916), had been complaining of symptoms of the stomach for two years, and during all this time had been under the care of a professor of therapeutics. When he finally asked a surgeon's opinion, exploration (Nov. 18, 1916) showed inoperable carcinoma of the stomach with malignant ascites; death occurred nine weeks after operation.

Precancerous Lesions.—We do not wish to engage in the unseemly philippic now raging in the medical journals over the question of ulcer

as a precancerous lesion of the stomach. Alvarez and MacCarty [13] are the authors of the now hackneyed quotation, "Gastric ulcers larger than a quarter (2.4 cm. in diameter) or carcinomas smaller than that are so rarely encountered that the physician with an average practice may go years without seeing one"; and MacCarty's estimate as to the high incidence of precancerous ulcer is well known, even if not acceptable to the majority of his colleagues. The English and continental authorities hold to a more conservative view, as do the majority of our own countrymen, and seem somewhat disinclined to accept all of MacCarty's histologic criteria of malignancy without question. The following two case histories suggest that though the symptoms of gastric ulcer may be relieved by gastrojejunostomy, yet carcinoma can actually develop in the ulcer or in the scar left by its healing.

WARD CASE 3808.—A man, aged 45, on Jan. 15, 1925, complained that for three months he had had constant epigastric pain, aggravated for about two hours after eating. Fifteen years before (1910) he had had a gastrojejunostomy performed elsewhere for ulcer of the stomach, when he was 29 years old. Exploration (1925) showed an inoperable mass on the lesser curvature near the cardia, with metastases to the right lobe of the liver and to the abdominal wall and umbilicus. The gastrojejunal anastomosis did not admit the finger. There was no obstruction to the cardia or the pylorus. Biopsy showed adenocarcinoma with a great increase of fibrous tissue. The patient died four months later. If the cancer had grown at the pylorus, and not at a site where symptoms are so often delayed, the patient might have come to operation early enough for hope of cure. He certainly had had carcinoma for more than three months, and for less than fifteen years.[14]

WARD CASE 3167.—A man, aged 40, on Dec. 18, 1923, complained of stomach trouble for the previous seven weeks. He had been having epigastric trouble for the previous seven weeks. He had been having epigastric cramps.

Eleven years previously (1912), a partial gastrectomy (Polya's) had been done (by Dr. Frazier, in this hospital) for a chronic ulcer on the lesser curvature which showed no evidence of a malignant condition under the microscope. Exploration (1923) showed a fixed inoperable mass on the lesser curvature with metastases to the liver. Death followed in two months. Necropsy was not permitted.

Ulcer is not the only lesion of the stomach held to be precancerous, for, as Miller [15] pointed out, benign polypus and even chronic gastritis

13. Alvarez, W. C., and MacCarty, W. C.: Sizes of Resected Gastric Ulcers and Gastric Carcinomas, J. A. M. A. **91**:226 (July 28) 1928.

14. Whether or not this carcinoma developed at the site of the former ulcer, perhaps in its scar, is uncertain. But as it is well known that gastrojejunostomy will not prevent the development of an ulcer in the stomach, it is not logical to expect it to heal such a lesion. It is our own firm belief that whenever possible an ulcer of the stomach should be treated by wedge resection or partial gastrectomy. Yet a carcinoma may develop contiguous to, but separate from, a chronic ulcer in the stomach, as in the case of Ernest M., whose history is summarized on pages 338 and 340. Moreover, even after a benign ulcer has been excised, carcinoma may develop after many years (Ward Case 3167).

15. Miller, T. G.: Precursors of Cancer of Stomach, Pennsylvania M. J. **34**: 170 (Dec.) 1930.

are known to be precursors of malignant growths. Sprunt [16] reported the coexistence in the stomach of tuberculosis and cancer, but carefully avoided any interpretation of the fact.

As we have shown that to rely entirely on symptoms for diagnosis is dangerous practice in gastric cancer, careful physicians and surgeons should take every means to investigate the possibility that their patient's symptoms might be due to carcinoma. The means of diagnosis, aside from symptoms, which have just been discussed, might be classified as follows:

I. Purely Clinical Methods
  (*a*) Palpable tumor
    57 per cent of our cases
    60 per cent of Oberniedermayr and Stahnke's series [12]
    (A freely movable palpable small tumor is more of a favorable sign than otherwise [Mayo], because it indicates that the growth is accessible.)
  (*b*) Cachexia
  (*c*) Coffee-ground vomitus
II. Laboratory Methods
  (*a*) Chemical examination of stomach contents and of stool:
    (1) For strength, concentration and type of acid
    (2) For occult blood
      (Rütimeyer estimates that this finding is positive in 100 per cent of cases; Anschütz, 94 per cent; Boas, 95 per cent [10]).
  (*b*) Microscopic examination of stomach contents for abnormal objects (Oppler-Boas bacilli; fragments of tumor)
  (*c*) Roentgen Diagnosis
    (A positive roentgen diagnosis is nearly 100 per cent perfect, but a negative is not.)
III. Unusual, New and Obsolete Means
  (*a*) Gastroscopy
  (*b*) Gastrophotography
  (*c*) Serum diagnosis
  (*d*) Pneumoperitoneum
  (*e*) Inflation or distention of the stomach
IV. Exploratory Laparotomy

Exploratory Laparotomy.—Exploratory laparotomy is sometimes the only means of ascertaining the truth. Nor should other means of diagnosis be persisted in too long, lest the stage of operability (even of palliative operation) pass without the diagnosis being certain. It is true that exploratory laparotomy is not infallible. Among the patients formerly included in the present series with gastric carcinomas were three on whom gastrojejunostomy was done under the impression that

16. Sprunt, D. H.; Carcinoma and Tuberculosis: Report of Case with Review of Literature, Surg., Gynec. & Obst. **51**:245 (Aug.) 1930.

the inoperable mass found obstructing the pylorus was carcinomatous; but as these three patients remained in good health more than three years after this palliative operation, they have been removed from the list of patients with cancer and transferred to the group with benign ulcers, thus reducing the number of patients with carcinoma from fifty-seven to fifty-four.[17]

In all other patients the correctness of the diagnosis has been proved either by the lesions found at necropsy, at operation (secondary nodules in liver, etc.), by laboratory examination of the excised specimen or by the patient's death. In a fourth patient, partial gastrectomy was done on a clinical diagnosis of carcinoma, but under the microscope no malignant condition could be found. Including these four patients, later classified as having ulcer instead of carcinoma, there were forty-six patients who, when their abdomens were opened, were thought to be suffering from carcinoma. Four errors in clinical diagnosis among forty-six patients is a percentage of less than 8.7. Certainly no other means of clinical diagnosis is any more accurate than exploratory operation. Furthermore, these errors are not objectionable because they resulted in proper treatment in spite of the error.

Roentgen Examination.—Apart from exploratory laparotomy, we believe roentgen study to be the most nearly infallible means of diagnosis (Dr. Ralph S. Bromer and his staff cooperated in the conduct of these studies). Yet many patients were so ill from starvation, and the clinical diagnoses so reasonably certain, that operation was done without the delay of roentgen study. It is interesting to note in passing that the first roentgenogram of the stomach was made in 1896, by an American, John Conrad Hemmeter.[18]

Gastric Analysis.—Though many brilliant contributions to pure science and the physiology of digestion have been made on the chemistry of digestion by chemists from the time of the first work by Young[19] in his graduating thesis from the University of Pennsylvania on "An Experimental Inquiry into the Principles of Nutrition and the Digestive

17. Schönbauer and Orator reported the case of one cancerous patient who survived gastro-enterostomy four years, and of another who survived sixteen and one-half years (Wien. klin. Wchnschr. **37**:79, 1924). Daneel recorded one seven year survival after gastro-enterostomy (Results in Gastric Cancer Cases Treated at the Heidelberg Clinic from 1898 to the End of 1905, Beitr. z. klin. Chir. **59**:283, 1908).

18. Hemmeter, J. C., cited by Garrison, F. H.: History of Medicine, ed. 3, Philadelphia, W. B. Saunders Company, 1922, p. 686.

19. Young, John R.: An Experimental Inquiry into the Principles of Nutrition and the Digestive Process, graduating thesis, University of Pennsylvania, 1803; cited by Garrison, pp. 329 and 505.

Process" (1803) through Beaumont [20] to the present, nevertheless, in actual practice we fail to lay as much stress on chemical analysis as some authorities, and can recall no case in which the results of such an analysis outweighed all other considerations. Even the demonstration of lactic acid is regarded as equivocal, as it has been proved to occur in noncancerous conditions.[21]

TREATMENT OF CANCER

No Operation.—On twelve of our patients no operation was attempted; three patients refused, and in nine it was considered useless to attempt even exploration. Only four of these twelve patients died in the hospital; of the eight discharged, three died within less than seven weeks; one was still living in misery when last heard from, a year later, and four could not be traced.

The average duration of life from the onset of the first symptom is a little over a year (15.7 months in a vast series of cases, 1919-1927, taken in the San Francisco Cancer Survey [22]).

Operation.—As was indicated earlier, there have been no known cures after treatment by electricity, light, radiant energy, drugs, chemicals or biologic products. Surgical removal of the lesion, for the present, is the only hope. Although surgery of the stomach has a long history, there being a record of an operation in 1625 on the stomach of a patient who had swallowed a knife,[23] it is only since Billroth's first successful pyloric resection in 1881 [24] that carcinoma in this organ has been cured. This brilliant Zürich professor, later of Vienna, heads a famous list of surgeons who distinguished themselves in this field—including his pupil, Johann von Mikulicz-Radecki (the first to use gloves in surgery, cotton ones, later superseded by rubber, introduced by Halsted), Vincenz Czerny, Anton Wölfler (first gastro-enterostomy, 1881), von Haberer, Finsterer and many others throughout the world. One of the reasons why there are no Billroths today is that there are so many of them. Today there are, in widely scattered regions, many surgeons capable of doing, almost as a routine, what was considered most unusual by the pioneers during the evolution of surgery of the stomach.

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20. Beaumont, W.: M. Rec. **8**:14, 1825; **9**:94, 1826; cited by Garrison, F. H., p. 506.

21. Dodds, E. C., and Robertson, J. D.: Lactic Acid and Carcinoma of the Stomach, Lancet **1**:171 (Jan. 25) 1930; Quart. J. Med. **23**:175 (Jan.) 1930.

22. Hoffman, F. L.: San Francisco Cancer Survey, 6th Preliminary Report, Newark, N. J., 1931, p. 12.

23. de Lint, J. G.: Operation in 1635 upon Stomach of Patient Who Had Swallowed a Knife, Æsculape **20**:223 (Aug.) 1930.

24. Billroth, Theodore: Wien. klin. Wchnschr. **31**:162, 1881.

Operability.—If a patient with carcinoma is to be cured he must belong to that class which lends itself to radical operation. In what proportion of patients with gastric cancer is there opportunity of performing a radical operation? The bar diagram in figure 4 shows the proportion, in percentage of the whole number of patients seen, that each type of exploratory, palliative and radical operation bears to the

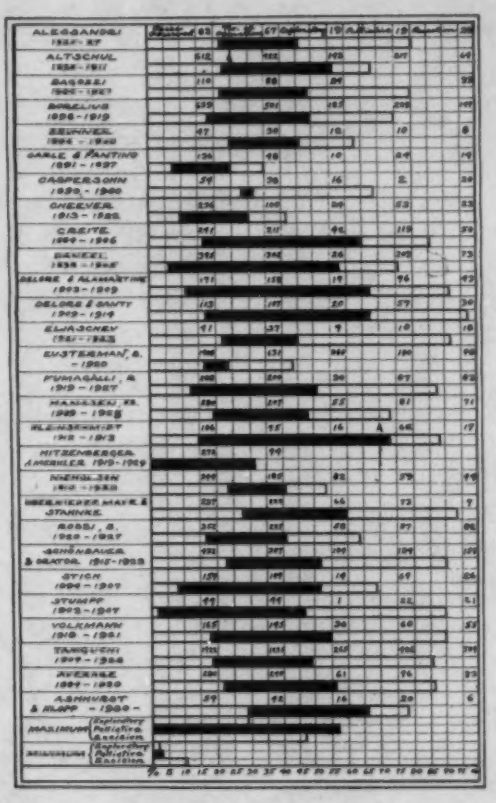

Fig. 4.—The proportion, in percentage, of all patients seen, and of each type of operation for carcinoma of the stomach. The white bar to the left represents exploratory operations; the black bar, palliative operations, and the white bar to the right, resections.

other two, and to the whole number of patients observed by the surgeon (table 1).

Whether or not these percentages are calculated from the whole number of patients seen or merely from those coming to operation makes a significant difference in the result. The wide variation in statistics depends, among other things, on this very influential factor. Careful selection of cases, with exclusion of those thought to be too

TABLE 1.—*Data in Cases of Gastric Carcinoma Observed by Various Authorities*

Years	Author	No. of Cases Observed	No. of Operations	Per Cent	Exploratory	Per Cent	Palliative	Per Cent	Resection	Per Cent
1920-1927	Alessandri	83	67	81	19	28	19	28	29	43
1914	Alexinski	...	...	..	...	..	...	..	297	..
1895-1911	Altschul	612	422	69	143	34	217	51	64	15
1924-1926	Balfour	...	113	..	48	42	19	16	46	40
1920-1927	Bagozzi	110	88	80	24	24	31	35	33	38
1903-1927	Bastianelli, P.	374	272	73	80	29	95	35	97	36
1928	Bastianelli, R.	...	543	..	128	23	176	32	293	44
1931	de Beule	258	247	96	...	..	51	20	197	79
1878-1890	Billroth	...	...	..	...	..	28	..	28	..
1912	Bindseil	...	...	..	...	..	38	..	...	..
1898-1919	Borelius	659	501	76	125	24	229	45	147	29
1896-1900	Brunner	47	30	64	12	40	9	30	10	33
1890-1905	Brunner	...	62	..	12	19	32	51	18	29
1891-1897	Carle and Fantino	136	48	35	10	20	24	50	14	29
1890-1900	Caspersohn	54	38	70	16	42	2	5	20	50
1913-1922	Cheever	236	100	42	24	24	53	53	23	23
1884-1906	Creite	241	211	88	42	19	119	56	50	23
1900-1920	Crossan	80	51	64	17	33	20	39	14	27
1881-1892	Czerny, R.	...	38	..	9	23	17	44	12	31
1898-1905	Daneel	395	302	76	26	8	203	67	73	24
1920	Deaver	...	...	..	...	..	...	..	46	..
1903-1909	Delore and Alamartine	171	158	92	19	12	96	60	43	27
1904-1914	Delore and Santy	113	107	95	20	18	57	53	30	28
1913	Derjushinsky	...	146	..	72	49	16	10	58	39
1896-1900	Eiselsberg	...	...	..	...	..	45	6	22	3
1921-1923	Eljaschev	41	37	90	9	24	10	27	18	48
1920	Eusterman and Bueerman	1,408	631	45	249	38	100	16	290	46
1913	Faroy	...	64	..	8	13	39	61	16	25
1912	Feurer	...	...	..	...	..	...	..	58	..
1910-1929	Finsterer	...	535	..	68	18	70	19	348	65
1927	Frank	77	62	80	32	52	9	11	21	34
1919-1927	Fumagalli	228	200	88	30	15	87	44	83	41
1913	Galpern	...	79	..	14	17	33	41	32	40
1920-1927	Gamerini	...	95	..	29	30	40	42	26	27
1912	Gar	...	...	..	...	..	...	..	18	..
1878-1894	von Hacker	...	...	..	...	..	51	..	42	..
1909-1923	Hanssen	280	207	74	55	26	81	39	71	34
1919-1929	Hitzenberger and Merkler	272	94	35	...	..	...	..	...	..
1895-1910	Hoffmann	...	309	..	55	18	144	46	103	34
1912-1913	Kleinschmidt	106	95	90	16	16	62	65	17	17
1911	Güttner	...	...	..	...	..	...	..	102	..
1891-1904	Makkas	...	458	..	68	14	223	48	163	35
1897-1919	Mayo, C.	...	2,094	..	746	35	612	29	736	35
1914	Mikaye	...	...	..	...	..	...	..	116	..
1803-1895	Mündler	...	20	..	5	25	11	56	4	20
1910-1930	Nicholson	344	185	54	82	44	50	32	44	24
1911	Nyström (all cases in Sweden in 1911)		...	..	...	..	...	..	225	..
1922-1926	Oberniedermayr and Stahnke	237	222	94	66	30	73	32	83	37
1887-1926	Persson	...	1,150	..	339	29	450	39	361	31
1903	Petersen	...	...	..	...	..	...	..	57	..
1928	Puccinelli	...	110	..	31	28	29	26	50	45
1908	Ribeira and Sans	...	93	..	14	15	50	53	29	31
1920-1927	Rossi, B.	352	227	65	58	25	87	38	82	36
1920-1927	Rossi, F.	228	200	88	30	15	87	44	83	41
1915-1923	Schönbauer and Orator	432	387	90	104	26	126	32	157	40
1928	Segre	...	34	..	3	9	21	62	10	29
1920-1927	Serafini	...	70	..	31	44	34	48	5	7
1914	Sherren	...	...	..	...	..	...	..	27	..
1895-1897	Steudel	...	60	..	8	13	45	75	7	11
1894-1908	Stich	150	109	68	14	12	69	63	26	23
1903-1907	Stumpf	49	44	90	1	2	22	50	21	47
1904-1923	Taniguchi	1,422	1,235	86	265	21	426	34	544	44
1911	Témoin	...	336	..	...	..	...	..	...	..
1920-1927	Vecchi	...	102	..	23	22	54	52	25	24
1918-1921	Volkmann	163	145	89	30	20	60	41	55	37
1929	Walton	262	204	78	(132)	65	(132)	65	62	31
1907-1911	Weil	445	364	82	128	35	116	30	120	32
1930	Ashhurst and Klopp	54	42	78	16	38	20	48	6	14

risky, will reflect itself largely in a favorable influence in the radical operability, as well as in the mortality, statistics. Unfortunately, as will be noted by a glance at table 1, many authors reckon as 100 per cent merely the number of patients operated on and not the total number submitted to their judgment. Balfour,[25] for example, modestly offers this fact, as a partial explanation of the clinic's favorable results in operations for peptic ulcer. Statistics, to be absolutely comparable, should include those patients who refuse operation, or whose condition is inoperable.

The average percentage of patients with carcinoma submitted to resection in the statistics of figure 4 is thirty, with a maximum of forty-six and a minimum of ten. Up to Jan. 1, 1930, out of a series of fifty-four patients with carcinoma of the stomach under the care of the senior author (Dr. Ashhurst), only six (11 per cent) were observed early enough for radical operation. Of these six patients, however, four (66 per cent) have survived their operation for seven years or longer, and may be reckoned as "five year cures":

Benjamin E., aged 43, operated on in 1919; well in April, 1932 (thirteen years).
Ernest M., aged 55, operated on in 1920; well in April, 1932 (twelve years).
Harry W., aged 60, operated on in 1925; well in April, 1932 (seven years).
John D., aged 68, operated on in 1925; well in April, 1932 (seven years).[26]
The results are the same to March, 1933.

The percentage of five year cures reported by surgeons may be distorted in all sorts of ways, as shown in figure 5 and table 2, which are self-explanatory. The important column is the percentage of the total number of patients under observation who obtain five year cures; a high figure in this column is an index of what is called "surgical judgment" (column 2, table 2 and the first bar in figure 5). A comparison of various surgeons' results is most difficult, since some report the percentage of survivors, others the percentage of those appearing in the end-result clinic.

The duration of life among the patients "cured" at least five years is sometimes remarkably long, considering the expectation of life at

25. Balfour, D. C.: Proc. Staff Meet., Mayo Clin. **5**:64 (March 5) 1930.

26. A fifth patient, John M., aged 45, who was operated on in 1921, was well in 1930 (nine years); but as there is disagreement between pathologists as to whether or not his lesion (excised from the lesser curvature) is or is not carcinoma, his case is not included. Reports of cures, such as that by Quigley, in which there is no reasonable proof of carcinoma, should be definitely so labeled in their titles (Three Cured Cases of Supposed Carcinoma of the Stomach, Nebraska M. J. **13**:338 [Sept.] 1928).

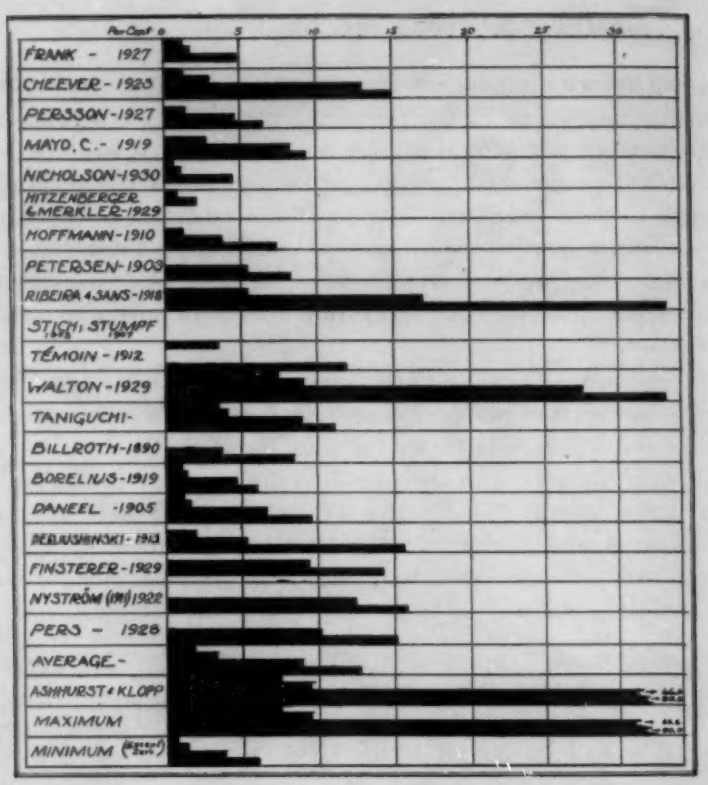

Fig. 5.—Percentage of five year cures. Reading from top to bottom, the first bar represents cures in percentage of all patients; the second bar, in percentage of all operations; the third bar, in percentage of radical operations, and the fourth bar, in percentage of survivors of resections.

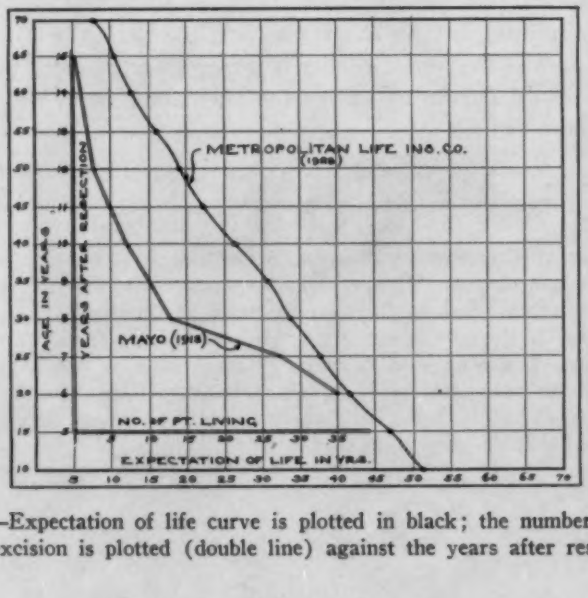

Fig. 6.—Expectation of life curve is plotted in black; the number of patients surviving excision is plotted (double line) against the years after resection.

the average cancer age.[27] (In figure 6 is shown the expectation of life curve drawn from figures of the Metropolitan Life Insurance Company, Industrial Department, 1928, for selected ages between 10 and 70 years.)

Exploratory Operation.—As indicated already, exploration was urged on every patient who we thought would survive. Some writers claim that the question of inoperability may be as easily decided by roentgenologic study as by exploration. This has not been our own experience. In spite of a negative roentgen examination, we once

TABLE 2.—*Five Year Cures in Cancer of the Stomach*

Date	Author	No. of 5 Year Cures	Per Cent of All Patients	Per Cent of All Operations	Per Cent of Radical Operations	Per Cent of Survivors of Resection
1927	Frank	1	1.3	1.6	4.8	...
1923	Cheever	3	1.3	3.0	13.0	15.0
1910	Paterson	...	...	1.4	4.7	6.5
1927	Persson	17	...	...	...	...
1918	Mayo, W. J.	..	...	...	26.0	...
1919	Douglas	..	...	...	27.0	...
1928	Pauchet	..	...	...	31.3	...
1919	Mayo, C.	59	...	...	8.1	9.3
1930	Nicholson	2	0.58	1.04	4.5	...
1929	Hitzenberger and Merkler	2	0.73	2.1	...	...
1910	Hoffmann	4	...	1.3	3.9	7.4
1903	Petersen	3	...	5.3	...	9.3
1908	Ribeira and Sans	5	...	5.4	17.1	33.3
1903	Stich	0	0	0	0	0
1907	Stumpf	0	0	0	0	0
1923	Taniguchi	49	3.5	4.0	9.0	11.1
1911	Témoin	12	3.5	...	12.0	...
1929	Walton	33	7.4	9.1	27.5	33.0
1890	Billroth	1	...	...	3.6	8.3
1919	Borelius	7	1.1	1.4	4.8	6.0
1905	Daneel	5	1.3	1.6	6.8	9.6
1913	Derjushinsky	3	...	2.0	5.2	15.8
1929	Finsterer	50	...	9.3	14.2	...
1922	Nyström	28	..	...	12.4	15.8
1930	Deaver	2	...	...	...	...
1930	Jones and Scott	1	...	...	...	...
1930	Schwyzer	1	...	...	...	...
1928	Pers	3	...	...	10.0	15.0
1925	Anschütz	20	...	...	...	...
1911	Küttner	27	...	...	...	...
1915	von Haberer	2	...	...	...	...
	Ashhurst and Klopp	4	7.4	9.5	66.6	80.0

27. Bloodgood[28] mentioned a twenty year survival after partial gastrectomy for cancer; Pers, two survivals, of twenty-two and one-half and nineteen and one-half years, respectively (Results Obtained by Resection in Cancer of the Stomach, Acta chir. Scandinav. **64**:405, 1928); Schwyzer, one of twenty-four years (Cancer of the Stomach: Case Without Recurrence Twenty-Four Years After Operation, Ann. Surg. **92**:540 [Oct.] 1930), and Weil, two, of nineteen and twenty-one years, respectively (Carcinoma of the Stomach, 1891-1911, Beitr. z. klin. Chir. **1115**:461, 1919). Of W. J. Mayo's patients (Cancer of Stomach, Surg., Gynec. & Obst. **26**:367 [April] 1918), thirty-five lived more than six years, with a gradual decline in the total number living, as shown in figure 6, in which the data have been superimposed on an expectation of life curve to show the similarity in shape. Balfour (Curability of Cancer of Stomach, Surg., Gynec. & Obst. **54**:312 [Feb. 15] 1932) reported from the Mayo Clinic one hundred and twenty-eight patients who lived ten years or more after radical operation. One of our survivors, Benjamin E. is living (April, 1932) at the age of 56, thirteen years after operation.

found a mass of carcinoma (unfortunately inoperable) high in the fundus of the stomach (greater tuberosity). Nor has a positive roentgenologic report, however unfavorable, ever deterred us from opening an abdomen in the hope of being able to do at least a palliative operation. In fact, it may be said that every one of these operations has been commenced as an exploration. Fortunately, in 62 per cent of these explorations it was possible to do either a radical (in 45 per cent of all operations) or a palliative operation (in 48 per cent of all operations), leaving only sixteen patients (38 per cent of the total operations), for whom nothing could be done. (In figure 4 the results of other authorities are compared.)

Mortality of Exploratory Operation.—The death rate in these sixteen exploratory operations was high (43.7 per cent), and all patients who survived and were sent home, except one, died in less than five months. The one exception is a man living, in miserable health, one year after exploration, who showed a carcinoma high on the posterior wall of the stomach (fundus) not causing obstruction, but with metastases in the liver.

The cause of death after exploration, whether death occurred while the patient was still in the hospital or after discharge, was attributed to the progress of the disease in every case except one; in the case excepted, pneumonia was the cause, death occurring four days after exploration under ether. If this were the only one to be recorded as a postoperative death, our operative mortality in exploration would fall from 43.7 to 6 per cent, which is nearer the figures given by many surgeons under these circumstances (fig. 7; table 3).

The following anesthetics were used in our exploratory operations:

Ether was used three times with two deaths: one from pneumonia on the fourth day, and the other from the patient's disease, after one week.

Nitrous oxide gas was used twelve times, with four deaths, all from the patient's disease, at intervals from twelve days to six weeks after operation.

Local anesthetic was used once, with death from the patient's disease forty-eight hours later. Perhaps it was an error to have performed an exploratory operation on so ill a patient.

It is our practice to get patients in whom exploration has been done out of bed early after operation, as they easily become bedfast and die.

Palliative Operation.—Palliative operation was done on twenty patients, or 30 per cent of the whole number seen, or 48 per cent of those subjected to operation. The operations were as follows: Gastrojejunostomy (fifteen posterior and one anterior) was done in sixteen

cases for pyloric obstruction. Gastrogastrostomy was performed once for hour-glass obstruction. Gastrostomy was performed in three cases for cardiac obstruction.

The following anesthetics were used in our palliative operations:

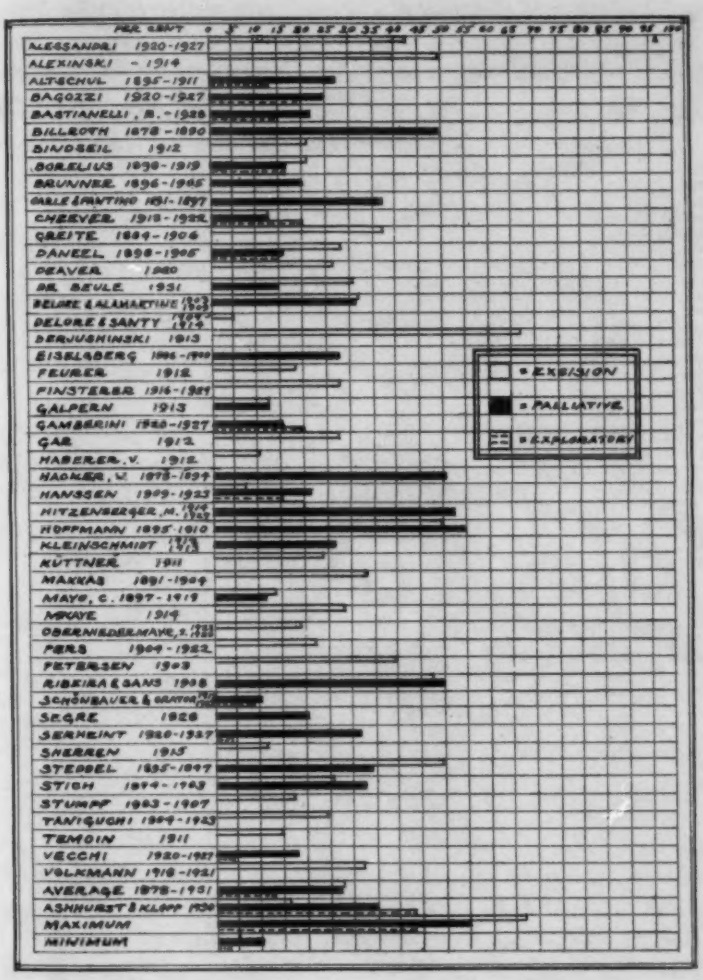

Fig. 7.—Operative mortality in cancer of the stomach for three types of operations.

Ether was used five times, with one death from surgical shock eighteen hours after operation.

Nitrous oxide gas was used eight times, with three deaths: one, after forty-eight hours, from the patient's disease; one, after seventeen days, from multiple pulmonary abscesses, and one, after one month, from progress of the disease.

Local anesthetic was used six times, with three deaths, all within a few days, from asthenia.

Spinal anesthetic was used once, with recovery.

TABLE 3.—*Operative Mortality of Various Types of Operation for Cancer of the Stomach*

Author*	Exploratory Deaths		Palliative Deaths		Resection Deaths	
	Number	Per Cent	Number	Per Cent	Number	Per Cent
Alexinski	..	..	..	..	148	50
Altschul	19	13	54	27	29	40
Bagozzi	5	20	8	25	14	42
Bastianelli, P.	9	11	22	25	21	21
Bastianelli, R.	..	15	..	21	..	28
de Beule	..	..	..	15	..	31
Billroth	..	..	14	50	16	56
Bindsell	..	..	..	..	8	21
Borelius	21	16	38	16	31	21
Brunner	8	26	..	..	..	..
Carle and Fantino	..	..	9	37	..	..
Caspersohn	..	..	..	..	11	55
Cheever	5	20	7	13	3	13
Creite	..	..	..	..	19	38
Crossan	7	41	10	50	5	36
Daneel	4	15	33	16	21	28
Deaver	..	..	..	..	12	26
Delore and Alamartine	..	..	..	38	14	33
Delore and Santy	..	..	..	..	1	5
Derjushinsky	..	..	..	..	39	67
Eiselsberg	..	..	13	28	7	31
Faroy	6	..	8	..	7	45
Feurer	..	..	..	..	11	19
Finsterer	..	..	..	..	..	19
Galpern	..	..	..	12	..	12
Gamberini	6	20	6	15	2	7
Gar	..	..	..	..	5	28
von Hacker	..	..	25	50	19	45
Hanssen	9	16	16	21	5	7
Hitzenberger and Merkler	..	..	50	..	20	..
Hoffmann	27	54	..	..	40	50
Kleinschmidt	..	..	12	26	..	..
Küttner	..	..	..	..	25	24
Makkas	..	..	..	..	57	34
Mayo, C.	22	2.9	67	11.1	..	13.7
Mikaye	..	..	..	..	3	11
Nyström	..	..	..	..	46	..
Oberniedermayr and Stahnke	19% mortality of all operations					
Persson	..	17	..	23	101	27
Petersen	..	..	..	..	..	40
Ribeira and Sans	..	..	24	50	14	48
Schönbauer and Orator	10	9	..	10	33	21
Segre	..	..	4	20	..	..
Serafini	1	8	10	31	..	..
Sherren	..	..	..	..	3	11
Steudel	..	..	16	35	..	..
Stich	..	..	19	34	7	26
Stumpf	..	..	..	..	2	9
Taniguchi	..	..	..	..	140	25
Témoin	..	..	..	..	100	15.5
Vecchi	1	4	10	18	6	24
Volkmann	..	..	..	..	18	32
Weil	..	..	..	..	31	25
Ashhurst and Klopp	7	44	7	35	1	16.6

* See table 1 for number of operations.

Mortality of Palliative Operation.—Our general mortality in palliative operation (35 per cent) is very high (fig. 7; table 3). Of the thirteen patients who survived, the subsequent history is known for eleven; these patients were discharged from the hospital and lived in comfort for periods varying from three to fourteen months before

being incapacitated by their final illness, which usually lasted only a few weeks. The patient who had the shortest period of relief after operation (three months) curiously enough had the longest period of disability (four months) before death. The patient with the longest period of good health (fourteen months) was a man of 77 years at the time of operation; fourteen months later he died suddenly, of angina pectoris, having had entire freedom from gastric symptoms since operation.

Table 4 shows the reasons why no radical operation could be undertaken on these twenty patients.

TABLE 4.—*Palliative Operations*

Name	Age	Nature of Growth	Metastasis	Patient's Condition	Lymph Nodes
Louis S.	60	Fixed	Liver and pancreas	Poor	++
Charles G.	52	Entire stomach	0	Fair	++
Lizzie W.	60	Movable	Liver	Poor	++
Jos. A.	64	Fixed	Ascites	Poor	++
Jos. B.	55	Movable	0	Very bad*	0
Paul K.	55	Fixed, cardia	0	Fair	0
Louis L.	63	Fixed	Liver	Poor	+
Julia S.	45	Fixed	0	Bad	+
Samuel E.	55	Fixed	Retroperitoneal	Fair	++
Albert L.	58	Movable	Liver and retroperitoneal	Fair	++
John W.	77	Fixed	Retroperitoneal	Fair	++
Bridget O'D.	55	Extensive, but movable at pylorus	None	Fair	++
John J.	60	Fixed	Liver and retroperitoneal	Poor	++
Peter C.	58	Fixed, cardia	Retroperitoneal	Fair	0
Freda B.	60	Fixed	Liver	Fair	++
George K.	?	Fixed	Retroperitoneal	Fair	00
Benjamin S.	79	Fixed	Retroperitoneal	Poor	?
Herbert K.	46	Fixed, invading colon	Retroperitoneal, ascites	Bad	++
Mary C.	48	Fixed	Liver and retroperitoneal	Poor	++
Gus S.	58	Fixed	Retroperitoneal	Fair	++

* Lost 75 pounds (34.2 Kg.) in last ten weeks.

We believe that palliative operations are worth doing in spite of the high early mortality. As Abernethy said of malignant disease in general, "To forbear to operate is to consign the patient to hopeless misery."

Radical Operations.—Only on six patients (less than 11 per cent of those treated) was it possible to attempt radical operation (fig. 4). This small percentage is not due to our selection only of the easiest cases, for partial gastrectomy was attempted in every case in which it was thought the patient would survive.

Mortality of Partial Gastrectomy.—One of the six patients died soon; a second died, probably of metastasis to the lung, four and one-half months later, and four are still (April, 1932) [26] living from seven to

thirteen years after operation (fig. 7; table 3). A summary of the records in the cases in which gastrectomy was performed follows:

CASE 1.—Benjamin E., aged 42, was admitted to the hospital on Aug. 2, 1919, and was discharged on October 20. He remained well for thitreen years. Following influenza in 1918, he had never been strong enough to work. His normal weight was 160 pounds (72.6 Kg.). In the three months before admission, it dropped from 144 to 125 pounds (65.3 to 56.7 Kg.). His chief complaint was weakness, loss of appetite and heaviness after eating, relieved by self-induced vomiting. For two months before admission, he had symptoms of pyloric obstruction. Roentgen examination showed retention.

Operation on August 8 (ether) disclosed a movable mass at the pylorus with enlarged lymph nodes in the gastrohepatic and gastrocolic omenta. There was no metastasis to the liver. Partial gastrectomy (fig. 8) was performed.[28]

The patient gained 25 pounds (11.3 Kg.) in three months following operation. The present weight (1932) is about 157 pounds (71.2 Kg.) and the patient has no complaints. He works daily as a clothing finisher. His appetite is normal, and he has no digestive disturbances except a tendency to constipation, relieved by an occasional dose of laxative. The abdominal scar is firm.

Laboratory examination showed a large callous ulcer involving nearly the entire circumference of the stomach. Histologic study revealed adenocarcinoma. The lymph nodes in the gastrohepatic and gastrocolic omenta showed carcinoma. (The patient was presented Oct. 28, 1925, at the meeting of the Clinical Congress of Surgeons in Philadelphia, clinic at the Episcopal Hospital.)

CASE 2.—Ernest M., aged 55 years, referred by Dr. H. M. Freas, was admitted to the hospital on Sept. 28, 1920, and discharged on October 23. He was well for twelve years. He gave a history of indigestion and belching for eighteen months; vomiting for nine months, lately coffee-ground vomitus, and a loss of 50 pounds (22.7 Kg.) in weight. Roentgen examination showed retention of one fourth of the barium sulphate meal after six hours. A mass, probably operable, was seen at the pylorus, with the crater of the original ulcer and a larger surrounding mass of carcinoma.

Operation performed on October 1 (gas and 90 cc. ether) disclosed a mass the size of an ordinary apple in the prepyloric region of the stomach, adherent to the pancreas, causing hour-glass deformity. There was no metastasis to the liver. Partial gastrectomy (Polya's) was performed; dissection of the stomach from the pancreas was difficult. The patient made an uneventful recovery.

He gained 35 pounds (15.9 Kg.) within one year after operation. Twelve years later, at the age of 67, his weight is normal (145 pounds [65.8 Kg.]); he has no digestive disturbances, but eats smaller meals and at shorter intervals than before operation. An occasional laxative is necessary. He works daily as a tool dresser.

Laboratory examination showed chronic perforation of the stomach at the lesser curvature on the posterior wall. Independent and contiguous was a carcinomatous ulcer about 8 cm. in diameter, occupying the entire remaining lumen of the stomach. Histologic study revealed colloid carcinoma of the stomach. No notes were made about the cut ends of the specimen. Gastrohepatic lymph nodes showed carcinoma in the capsule, probably from direct extension. The lymph nodes in

28. Polya's technic was used. Convalescence was delayed by a bad infection of the abdominal wound, attributed to the neglect of the operators to change their gloves after completing the gastrectomy. The secondary suture of the incision was done on November 21.

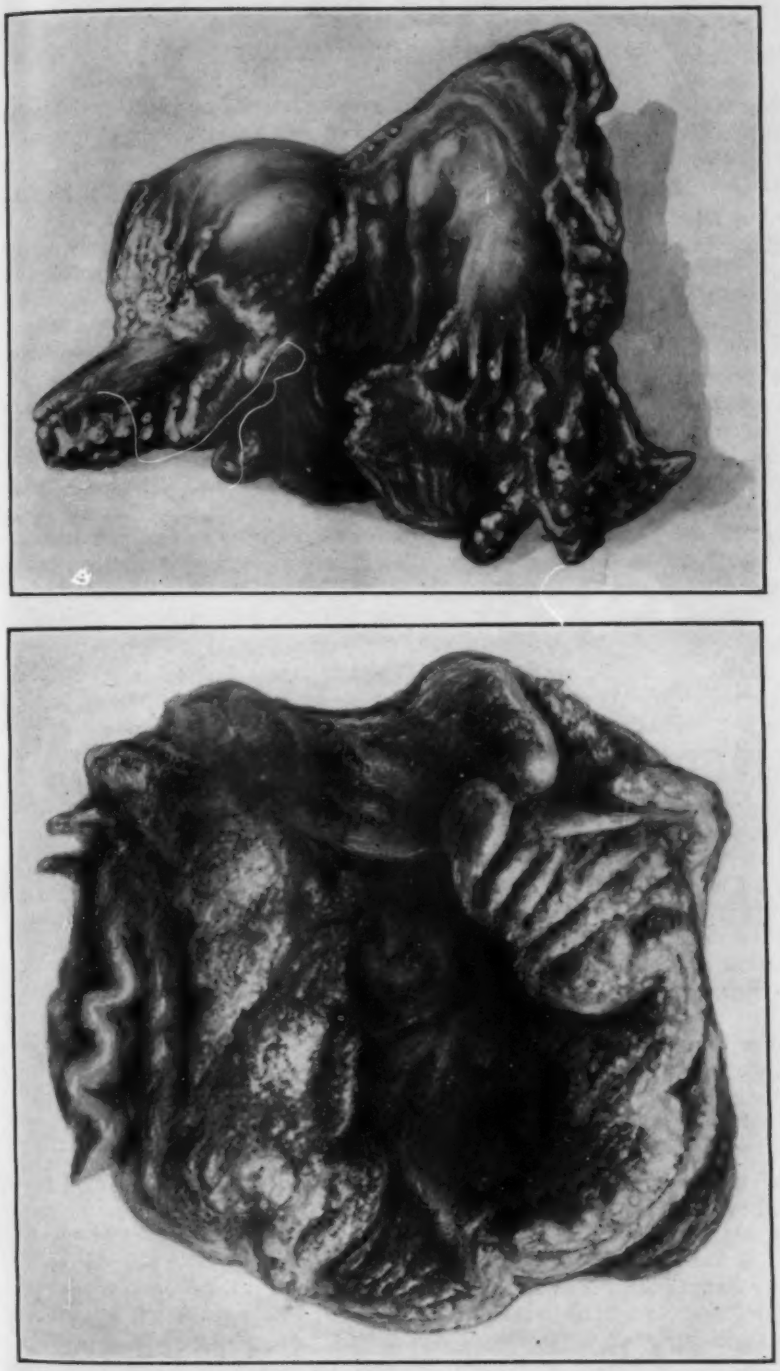

Fig. 8.—Adenocarcinoma of stomach in a man 42 years of age, with invasion of lymph nodes. The specimen (secured by partial gastrectomy in 1919) is shown intact above. In the lower cut the specimen has been opened along the lesser curvature, and the anterior wall of the stomach turned down, exposing ulcerated carcinoma involving almost entire circumference of stomach. The patient (Benjamin E.) was well over thirteen years after operation. (Courtesy of P. Blakiston's Son & Company, Philadelphia.)

the gastrocolic omentum showed doubtful carcinoma. (The patient was presented Oct. 28, 1921, and Oct. 28, 1925, at meetings of the Clinical Congress of Surgeons in Philadelphia, clinic at the Episcopal Hospital.)

Case 3.—Julia E., aged 65, was admitted to the hospital on Sept. 25, 1921, and died on September 29, forty-eight hours after operation. She complained of vomiting, nausea and loss in weight of 34 pounds (15.4 Kg.) during five or six months. Lately she had frequently vomited coffee-ground material. A roentgenogram was not taken.

Operation on September 27 (gas) disclosed a tumor in the body of the stomach, from one curvature to the other, with enlarged lymph nodes in the gastrohepatic and gastrocolic omenta. No metastasis was found in the liver. Subtotal gastrectomy (Polya's) was performed. The patient had to be catheterized three times after operation, and had gastric lavage three times for vomiting. Death occurred forty-eight hours after operation from asthenia. Necropsy showed anastomosis intact and no peritonitis; metastasis in the right lobe of the liver was not disclosed at operation.

Laboratory examination showed, on the lesser curvature, an ulcer 7 cm. in diameter, circular, with indurated raised walls; the cardiac section was only from 1.5 to 2 cm. from the ulcer; the pyloric section, 5 cm. from the ulcer. Histologic study showed medullary carcinoma. No notes were made on the cut ends of the specimen or on the lymph nodes.

Case 4.—Mary T., aged 75 years, referred by Dr. R. S. Hooker, was admitted to the hospital on April 12, 1924, and was discharged on April 30. Death occurred four and one-half months after operation. For eight weeks preceding admission, she had epigastric pain, and for the past two or three weeks, vomiting. The normal weight was 145 pounds, but she lost 43 pounds (19.5 Kg.) in eight weeks. A roentgenogram showed retention of three fourths of the opaque meal after six hours, and a filling defect at the pylorus.

Operation performed on April 5, 1924 (gas) disclosed a mass at the pylorus, but no metastasis to the liver. Partial gastrectomy (Polya's) was done. The patient's recovery was uneventful.

The patient was comfortable till a few weeks before death (Aug. 27, 1924), four and one-half months after operation, after an illness characterized by cough and expectoration (probably pulmonary metastasis). No necropsy was performed.

The specimen measured 12 cm. on the lesser curvature and 15 cm. on the greater curvature; the duodenal end passed 2 or 3 cm. beyond the gross lesion, and the cardiac end, 5 or 6 cm. Histologic study revealed adenocarcinoma; lymph nodes in both the gastrohepatic and gastrocolic omenta showed early carcinoma; the pyloric cut end of the specimen showed carcinoma; the cardiac cut end showed no carcinoma.

Case 5.—Harry W., aged 60, was admitted to the hospital on Jan. 7, 1925, and was discharged on March 6. He was well for seven years. The chief complaint was pain after eating for five months previous to admission, relieved by vomiting. He had lost 23 pounds (10.4 Kg.) in weight. A roentgenogram showed retention of one sixth of the barium sulphate meal after six hours; there was a filling defect in the prepyloric region, probably from adhesions; "if a carcinoma it was probably small and operable."

Operation performed on January 19 (gas) disclosed a freely movable mass at the pylorus; there was no metastasis to the liver; enlarged lymph nodes were seen in the gastrohepatic and gastrocolic omenta. Partial gastrectomy (Polya's) was done. Recovery was complicated by persistent hiccup from Jan. 23 to 31, 1925. One stitch abscess developed.

The patient was in good health in April, 1932, seven years after operation.

The operative specimen measured 11 cm. on the lesser curvature, and 16 cm. on the greater curvature. There was an annular carcinoma at the pylorus. The pyloric section passed 2 cm. distant from the gross lesion, but a record concerning the cardiac end was lost. Histologic examination showed adenocarcinoma. The cardiac cut end showed freedom from carcinoma. The gastrocolic omentum lymph nodes and one lymph node from the gastrohepatic omentum showed carcinoma.

CASE 6.—John D., aged 68 years, was admitted to the hospital on Feb. 10, 1925, and discharged on March 16. He was well for seven years. For six months he had constant gnawing pain in the epigastrium, beginning one or two hours after meals, which was sometimes relieved by eating. Lately he had belching and small amounts of vomitus and lost 25 pounds (11.3 Kg.). A roentgenogram showed a filling defect at the pylorus, but no obstruction.

Operation performed on February 11 (gas) disclosed a movable mass at the pylorus; there was no metastasis to the liver; the lymph nodes beneath the pylorus and in the gastrocolic omentum were enlarged. Partial gastrectomy (Polya's) was performed, followed by an uneventful recovery. Seven years later, in April, 1932, the patient, then aged 75, was well, except for the feebleness of age. A roentgenogram (January, 1930) showed no carcinoma in the stomach; no obstruction at anastomosis, and a shadow in the lung suspected of being due to metastasis. Clinically, there were no symptoms or physical signs of a pulmonary lesion as late as April 15, 1932.

The specimen measured 10.5 cm. on the lesser curvature, and 18.5 cm. on the greater. Histologic examination showed adenocarcinoma; both cardiac and pyloric cut ends of the specimen showed carcinoma.[29]

Lymph nodes in both the gastrohepatic and gastrocolic omenta showed carcinoma.

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29. I have reviewed the slides of this specimen, and I can find none which shows this at the cut ends. The slides found show, in my opinion, freedom from carcinoma or any question of carcinoma at the cardiac and pyloric sections (J. W. K.).

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LYMPHATIC DRAINAGE OF JOINTS

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Very little is known concerning the lymphatic drainage of joints, although much has been written about the lymphatics of the other serous cavities. In the textbooks on anatomy, and even in the larger atlases, one rarely finds mention of lymphatics in joint cavities. The normal physiology of the lymphatics draining joint cavities and the functional disturbances which they manifest in disease are understood even less clearly. Since the discovery of lymphatic vessels by Asellius in 1622, many studies have been made to determine their presence and distribution in various parts of the body, but little has been learned of their function. The study of articular lymphatics was neglected until interest was aroused in the complex anatomy and physiology of the joints.

The study and dissection of the lymphatics by early investigators [1] led them to conclude that there were two channels of lymphatic drainage in the limbs, a deep and a superficial trunk. The superficial trunk in the lower extremity accompanied the great saphenous vein and was believed to drain all the tissues above the superficial muscular fascia, into the popliteal and inguinal lymph nodes. The deep trunk in the lower extremity followed the femoral vein and drained the tissues beneath the superficial fascia into the popliteal, deep femoral and iliac lymph nodes. In the upper extremity the superficial trunk followed the cephalic and basilic veins to the deep cubital nodes, to the lateral axillary and to the deep pectoral and infraclavicular nodes. The deep trunk followed the deep blood vessels to the deep cubital and axillary lymph nodes. Until recently it was believed that deep and superficial lymphatic systems had no intercommunication until they united along the femoral or external iliac vein in the lower extremity or in the axilla in the upper extremity. Baum,[2] however, in 1925 demonstrated lymphatics piercing the superficial muscular fascia in the horse, apparently uniting the deep and superficial systems. Miller,[3] in 1919, observed lymphatics in the lung between the pleural and parenchymal systems which functioned as anastomoses in cases of obstruction. Previously,

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these two systems in the lung had been considered wholly separate. The present conception seems to be that while intercommunications do exist between the deep and superficial lymphatic systems in the extremities, normally these systems function as separate entities.

The first studies of the lymphatics were made by observing the absorption of fat through the lacteals of the intestinal tract after the feeding of fat to animals. A little later attempts were made to make injections directly into the lymphatics. Retrograde injections with metallic mercury were made after tying off the thoracic duct. By this method the larger trunks only were shown, since rupture of the lymphatic wall soon occurred under the pressure of the material injected. Teichmann,[4] in 1861, was able to show only large lymphatic vessels in the lower extremity by retrograde injections of metallic mercury. Lee[5] found that retrograde injections were possible for only a few centimeters after ligation of the thoracic duct in cats. John Hunter[6] was particularly skilful in this method, and many of his specimens are still to be seen in the museum of the University of Glasgow.

Direct injections into the lymphatics in the direction of the lymph flow have always been extremely difficult. The small lymphatic vessels could not be found readily and attempts at injection with colored solutions soon ruptured the thin lymphatic wall. Florey and Carleton[7] have recently reported direct injections into the smaller lymphatics of the diaphragm with a fine glass pipet. They found that rupture of the lymphatic capillary occurred at 2.5 cm. of water pressure. In attempts to make injections into the lymphatic vessels at their entrance to lymph nodes, I was able to obtain an injection for only a few inches before the lymphatic vessel ruptured. Under normal conditions, in retrograde injections the lymphatic vessel wall ruptured before the valves within the lymphatic vessel became incompetent.

These difficulties in the demonstration of lymphatic vessels by direct injection led to attempts to make injections into them indirectly. It was found by Bowditch,[8] in 1873, that lymphatics could be traced fairly well by injecting dyes mixed with turpentine directly into thin sheets of tissue. Gerota,[9] in 1896, with a similar method was able to trace lymphatics for a short distance by injections directly into the tissues of

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7. Florey, H., and Carleton, H. M.: Brit. J. Exper. Path. **8**:479, 1927.

8. Bowditch, H. P.: The Lymph Spaces in Fascia: A New Method of Investigation, Boston, D. Clapp & Son, 1873.

9. Gerota, D.: Anat. Anz. **12**:35 and 216, 1896.

animals immediately after death. With the technic described by Gerota, Hermann Baum [10] has made an exhaustive study of the lymphatic system, particularly in cattle and horses. Injections of dyes directly into the tissues have been used in recent studies on the lymphatics by Henderson,[11] Hashiba,[12] Higgins,[13] Dewey and Noyes,[14] Mouchet,[15] Brain,[16] Jossefoff,[17] Horton [18] and Rienhoff.[19]

These methods, while giving a fairly satisfactory picture of the lymphatic distribution, have failed to show clearly the finest ramifications. To correct this fault in the older methods, Magnus,[20] in 1922, devised a method for showing the finer lymphatics by the use of hydrogen dioxide. He found that when hydrogen dioxide was brought in contact with living tissues the lymphatic vessels became filled with oxygen gas, owing to a catalytic action of the lymph on the hydrogen dioxide. To a slight extent the blood vessels also became dilated, but the investigators who have used this method, Rostock,[21] Stubel [22] and Magnus,[23] have found that this was a negligible factor, since the blood vessels could be easily differentiated from the lymphatics. This method was found useful for small sections of tissue which were studied microscopically with either transmitted or reflected light. Recently, Brown,[24] Fisher [25] and Rynearson [26] have studied lymphatics by using dilute solutions of colloidal silver. The colloidal silver in very dilute solution was injected directly into a serous cavity, from which it was taken up by macrophages and carried into the lymphatics. After several hours the

10. Baum, H.: Das Lymphgefäss-system des Rindes, Berlin, A. Hirschwald, 1917; Anat. Anz. **63**:122, 1927; Deutsche tierärztl. Wchnschr. **35**:413, 1927.

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26. Rynearson, E. H.: Proc. Staff Meet., Mayo Clin. **3**:171, 1928.

tissue lining the serous cavity was removed and studied microscopically by transmitted light. The lymphatic vessels were then seen as tiny, brown-filled channels coursing through the tissues.

While methods of demonstration were still rather crude, a number of important findings were made in regard to the lymphatics of the joints and bones. Ludwig and Schwagger-Seidel,[27] about 1870, injected colored substances into joints, and reported the absence of lymphatics in the synovial membrane and the joint capsule. Budge,[28] in 1873, working with cats, found a rich network of lymphatics in the periosteum, substantia compacta and marrow cavity of bone, but he made no mention of lymphatics about the joints. The first demonstrations of lymphatic vessels in articular structures were made by Tillmans[29] in 1876. A solution of Berlin blue was injected into the knee joint of a dog that had just been killed, by a hole bored through the femoral condyle. By alternately flexing and extending the lower leg for one hour, he was able to show blue dye in the synovial membrane and in lymphatic vessels almost to the middle of the thigh. Later, working with larger joints (horse and ox knee joints), he made injections directly into the synovial membrane. Here he found a deep and a superficial layer of lymphatic vessels, a dense plexus just beneath the serous coat of the synovial membrane and a smaller number of lymphatic vessels near the bones or ligaments to which the synovial membrane was attached. Magnus[30] described a similar arrangement of lymphatic vessels in the capsules of joints. Lymphatics in the synovial membrane were also demonstrated by Baum[31] after the direct injection of dyes into the capsules of joints.

EXPERIMENTAL DATA

The study reported in this article was begun five years ago in an attempt to find out the nature of the joint lymphatics in the lower extremity and their drainage, and, then, any possible relationship of lymphatic drainage to arthritis. In the early part of this work india ink in 10 per cent gelatin, prussian blue in 10 per cent gelatin and Gerota's mixture of prussian blue in turpentine and ether were used. Injections were made into the deep or the superficial tissues of the lower extremities soon after the death of animals that had been used for other lines of research; dogs, cats, rabbits and guinea-pigs were used. When the injection mass was injected into the subcutaneous tissues, it could be traced along the superficial blood vessels to the popliteal, inguinal and iliac

27. Ludwig and Schwagger-Seidel, quoted by Schdanow, D. A.: Anat. Anz. **69**:194, 1930.

28. Budge, A.: Arch. f. mikr. Anat. **13**:87, 1877.

29. Tillmans, H.: Arch. f. mikr. Anat. **12**:649, 1876.

30. Magnus, G.: Deutsche Ztschr. f. Chir. **182**:325, 1923.

31. Baum, H.: Deutsche Ztschr. f. Chir. **195**:241, 1927.

lymph nodes. When the injection was made under the deep muscular fascia, the substance could be traced in the lower leg to the popliteal and lumbar lymph nodes, but it was never found in the inguinal nodes. Attempts were made to show lymphatic drainage by the x-rays. Dilute suspensions of barium (Hill [32]) and brominized lard oil (Putnam [33]) were used. Although in these experiments deposition of the injected material was shown in a few of the lymph nodes on microscopic examination, the lymphatic vessels could not be demonstrated in x-ray films.

These aforementioned methods were of necessity crude. The dye was forced into tissue spaces, and the trauma may have ruptured a number of the smaller lymphatics into which the injected mass then passed, although the recent work of Drinker and Field [34] offers another explanation which will be considered later. Such injections into tissues or articular cavities of dead animals did not give satisfactory demonstrations of the lymphatics. The anatomists who have used this method obtained an adequate portrayal of the lymphatics only by studying a very large number of specimens, each of which showed some one phase, from which a composite picture of the drainage was secured.

After these preliminary attempts to gain familiarity with the methods and technic, injections of india ink were made directly into the joints of living animals. Young adult animals were used. Light ether anesthesia was given in order to prevent extravasation of the ink into periarticular structures, a common error, if the animal moved while the injection was being given. Injections of india ink into the tibioastragalar joint were made in six rabbits. The lymphatic drainage was traced through the so-called deep system to the popliteal and to the external and common iliac lymph nodes.

Rabbit 1.—Light ether anesthesia was given. The hair was shaved about the right ankle, and the skin was painted with 3 per cent iodine. The usual aseptic technic was followed. With a 25 gage needle, 0.25 cc. of india ink (diluted with an equal volume of distilled water) was injected into the right ankle joint on its anterolateral aspect. The animal was killed with chloroform five days later. There was no extravasation of ink in the subcutaneous tissues about the ankle. The ankle joint was deeply stained with ink. One lymphatic vessel was traceable along the posterior tibial vein almost to the middle of the tibia. The popliteal lymph node was stained a deep black from the india ink; no staining was observable in the inguinal lymph nodes. The lymph nodes along the common iliac and external iliac vessels were moderately stained with india ink. No lymph nodes along the inferior vena cava, beneath the diaphragm or in the mediastinal cavity showed any deposition of ink. Sections were taken from the capsule of the joint and from the lymph nodes mentioned for microscopic study.

32. Hill, E. C.: Bull. Johns Hopkins Hosp. **35**:218, 1921.

33. Putnam, T. J.: Some Brominized Oils for Radiographic Use, J. A. M. A. **87**:1102 (Oct. 2) 1926.

34. Drinker, C. K., and Field, M. E.: Am. J. Physiol. **97**:32, 1931.

RABBIT 2.—This animal was discarded because of marked extravasation of india ink into the subcutaneous tissues. There was moderate staining of the popliteal, inguinal and iliac lymph nodes.

RABBIT 3.—The technic was the same as for rabbit 1; 0.25 cc. of india ink was injected into the left ankle joint. The animal was killed in four days. There was no extravasation about the ankle joint. The ankle joint cavity was stained a deep black. No lymphatic vessels were seen about the ankle joint. The popliteal lymph node was deeply stained by the india ink. There was no visible absorption of ink in the inguinal nodes. There was a moderate amount of india ink in the iliac lymph nodes. Sections were taken from the capsule of the joint. The popliteal, inguinal and common iliac lymph nodes were removed for further study.

RABBIT 4.—The technic was the same as for rabbit 1; 0.25 cc. of india ink was injected into the left ankle joint. The rabbit was killed five days after the injection. There was slight extravasation of india ink about the ankle joint. A small lymphatic vessel could be traced from the fibular side of the left ankle joint to the middle of the calf. The popliteal lymph node was deeply stained. There was no evidence of absorption of india ink in the inguinal lymph nodes. There was a moderate absorption of india ink in the external iliac and in the common liac lymph nodes. Tissue was taken from the capsule of the joint and from the popliteal, inguinal, iliac and subdiaphragmatic lymph nodes for histologic study.

RABBIT 5.—The technic was the same as for rabbit 1; 0.25 cc. of india ink was injected into the right ankle joint. The rabbit was killed three days after the injection. No extravasation was seen about the ankle joint. Some ink was found in the posterior compartment of the joint. The popliteal lymph node was black with india ink. One small lymphatic vessel could be traced downward for about one-half inch (1.27 cm.) from the popliteal lymph node. The inguinal lymph nodes showed no absorption of india ink. There was a slight amount of india ink in the iliac lymph nodes. There was no evidence of absorption in the more proximal lymph nodes. Sections were taken from the capsule of the joint and from the popliteal, inguinal, iliac, epigastric and mediastinal lymph nodes for microscopic study.

RABBIT 6.—The same technic was used as for rabbit 1; 0.25 cc. of india ink was injected into the right ankle joint. The animal was killed four days later. There was no extravasation of the india ink. Much ink was seen in the posterior part of the ankle joint. The popliteal lymph nodes were much blackened from the india ink. No lymphatic vessels were seen. The inguinal lymph nodes showed no evidence of absorption of ink. A moderate amount of ink was seen in the common iliac lymph nodes. There was no evidence of absorption in any more proximal lymph nodes. Tissue was taken from the capsule of the joint and from the popliteal, inguinal and commom iliac lymph nodes for study.

After injections into the ankle joints no limitation of motion was noticed in any of the animals after the first day. There was apparently a rapid absorption of the ink from the articular cavity. The ink was found in largest amount about the posterior margin of the ankle joint. This space is less constricted by overlying tendons, which, apparently, play the chief rôle in moving intra-articular substances to various parts of the ankle joint. As a rule, the particles of ink were scattered fairly

uniformly throughout the subserous synovial tissues in the microscopic sections. Phagocytic cells loaded with particulate matter were seen in one section in a lymphatic capillary. No phagocytosis by cells lining the synovial cavity was observed. In some cases there was a slight polymorphonuclear infiltration of the synovial tissues. There was occasional, scattered, lymphocytic infiltration about the blood vessels and in the tissues when the animals lived more than several days (fig. 1).

The popliteal lymph nodes showed many of the lymph sinuses packed with phagocytic cells filled with india ink. There was a tendency for the particulate matter to become concentrated in the germinal center of the lymph node. This became more marked the longer the animal was permitted to live. There were some free particles in the lymph spaces, apparently from the cells that had disintegrated. The lymph nodes did not suggest any evidence of inflammation or venous congestion. None of the inguinal lymph nodes showed any absorption of the india ink. The external and common iliac lymph nodes showed only scattered groups of phagocytic cells filled with ink. The amount that they contained was always greater in the animals living a longer number of days after injection. No absorption of india ink was found in any lymph nodes above the bifurcation of the aorta. The other tissues comprising the reticulo-endothelial system, such as the liver, spleen and bone marrow, were not studied. Key [35] and others have found dyes in the liver, spleen and bone marrow after injection into articular cavities.

In order to determine whether there would be any alteration in the lymphatic drainage, the popliteal lymph nodes, the chief draining reservoir of the ankle joint, were removed from two rabbits.

Rabbit 1.—Ether anesthesia was given, with the usual aseptic technic. Through a midline incision in the popliteal space, the popliteal lymph nodes on the right side were removed. The skin and superficial tissues were closed with silk sutures; 0.25 cc. of india ink was then injected into the right ankle joint. The animal was killed four days later. Dissection showed that all lymph nodes had been removed from the popliteal space. The ankle joint showed no extravasation of the ink. The capsule of the joint was deeply stained, and there was a large amount of the ink in the posterior part of the ankle joint. There was no absorption of ink in the inguinal lymph nodes. The common iliac lymph nodes were deeply stained with ink. There was no evidence of absorption of the ink in any more proximal lymph nodes. Sections of the capsule of the joint and of the inguinal and iliac lymph nodes were removed for microscopic study, which confirmed the macroscopic findings. There was no ink in the microscopic section of the inguinal lymph nodes. There was a large amount of ink in the sections from the external and common iliac lymph nodes.

Rabbit 2.—The technic was the same as for rabbit 1. The left popliteal lymph nodes were removed. This was followed by the injection of 0.25 cc. of ink into the left ankle joint. Three days later the animal was killed. There was

35. Key, J. A.: J. Bone & Joint Surg. **8**:666, 1926.

no extravasation about the ankle joint. There was a moderate amount of india ink, particularly in the posterior part of the ankle joint. Dissection showed that the popliteal lymphoid tissue had been completely removed. No lymphatic vessels were seen. The inguinal lymph nodes showed no india ink. The common iliac

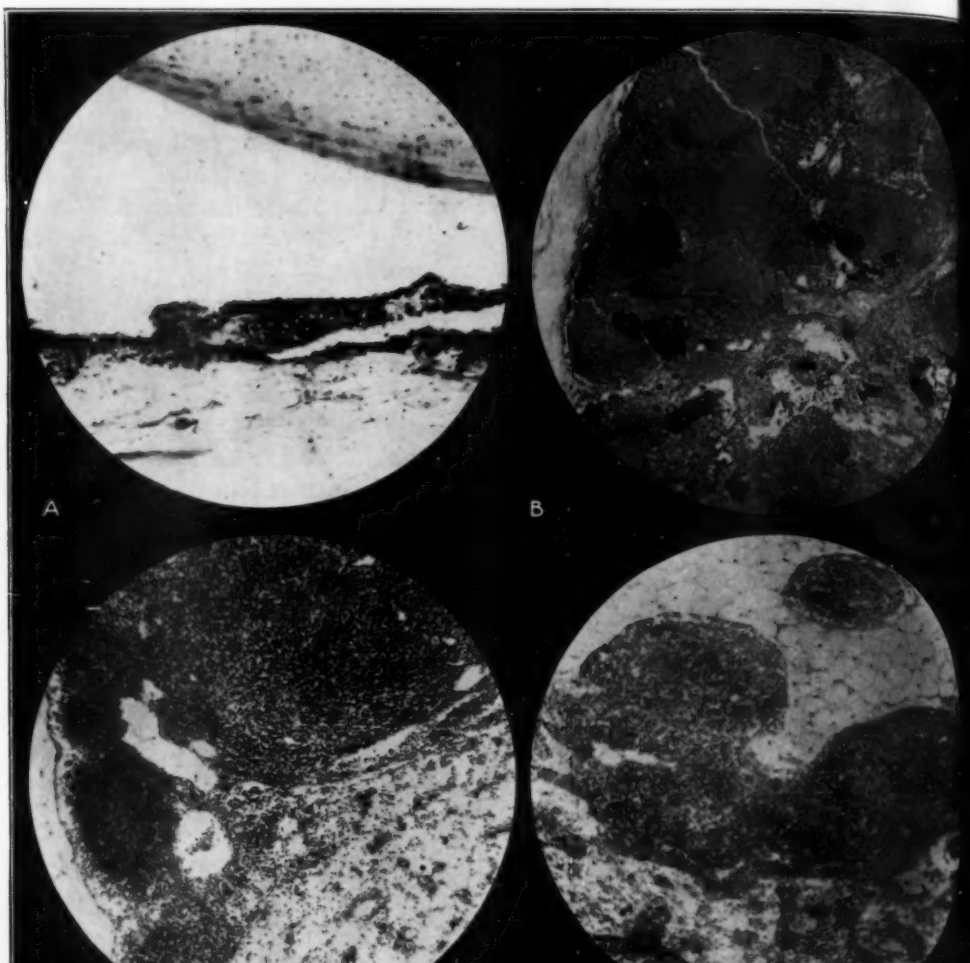

Fig. 1 (rabbit 3).—*A*, ankle joint, showing india ink in synovial membrane; reduced from × 110. *B*, popliteal lymph node, showing india ink in lymph follicles; reduced from × 70. *C*, inguinal lymph node, showing no absorption of india ink; reduced from × 70. *D*, common iliac lymph node, showing slight absorption of india ink; reduced from × 70.

lymph nodes were deeply stained with ink. No ink was found in any higher lymph nodes. The microscopic observations were the same as in rabbit 1.

Such experimental removal of lymph nodes is of doubtful value. Krause [36] observed the growth of lymphatics in newly formed tissue, in 1863. Sabin,[37] in 1916, reported that lymphatics regenerate slowly from their endothelial walls after injury. Reichert,[38] in 1926, showed in dogs that the superficial lymphatics regenerated in about four days and the deep lymphatics in eight days. Wocksmuth,[39] Baum [40] and Meyer [41] found, after the extirpation of lymph nodes, that the lymphatic drainage through the area was reestablished, although no regeneration of the lymph nodes occurred. In the animals used in this study, when the popliteal nodes were removed, the drainage passed on to the external iliac lymph nodes, the next proximal lymph nodes of the deep system in the rabbit draining the ankle joint. In such cases the iliac lymph nodes were as deeply stained by the india ink as the popliteal lymph nodes had been in the previous series of rabbits. Reports have appeared in the literature (Hirsch [42] and Cadenat [43]), in which removal or fibroses of lymph nodes led to elephantiasis or swelling of the extremity.[44] However, as Halsted [45] showed in elephantiasis of the arm, Homans and Zollinger [44] in phlegmasia alba dolens and Davis [46] in genital elephantiasis, an associated phlebitis was necessary to produce the condition.

In six rabbits injections of india ink were made directly into the knee joint. In these animals the lymphatic drainage was forced through the so-called deep system to the external and common iliac lymph nodes (fig. 2).

Rabbit 1.—Ether anesthesia was used. The hair over the right knee was shaved, and the skin was painted with alcohol and iodine. The usual aseptic technic was followed; 0.4 cc. of india ink was injected into the right knee joint. Four days later the animal was killed. There was deep staining of the synovial membrane. There was no evidence of absorption into the popliteal lymph node. The inguinal lymph nodes showed no evidence of the ink. The external and common iliac lymph nodes were deeply stained. A lymphatic vessel could be traced from the joint through Hunter's canal almost to the middle of the thigh. No lymph nodes above the common iliac lymph nodes showed any absorption of

36. Krause: Deutsche Klin. **15**:377, 1863.

37. Sabin, F. R.: Harvey Lectures, 1915-1916, Philadelphia, J. B. Lippincott Company, 1917, p. 124.

38. Reichert, F. L.: The Regeneration of the Lymphatics, Arch. Surg. **13**:871 (Dec.) 1926.

39. Wocksmuth, W.: Deutsche Ztschr. f. Chir. **208**:1, 1928.

40. Baum, H.: Deutsche Ztschr. f. Chir. **195**:241, 1926.

41. Meyer, A. W.: Bull. Johns Hopkins Hosp. **17**:185, 1906.

42. Hirsch, F.: Deutsche med. Wchnschr. **52**:1339, 1926.

43. Cadenat, F. M.: Bull. et mém. Soc. nat. de chir. **56**:1184, 1930.

44. Homans, J., and Zollinger, R.: Experimental Thrombophlebitis and Lymphatic Obstruction of the Lower Limb: A Preliminary Report, Arch. Surg. **18**:992 (April) 1929.

45. Halsted, W. S.: Bull. Johns Hopkins Hosp. **32**:309, 1921.

46. Davis, D. M.: Ann. Surg. **92**:400, 1930.

india ink. Sections were taken from the joint capsule and from the popliteal, inguinal and external iliac lymph nodes for study.

RABBIT 2.—The technic was the same as for rabbit 1; 0.4 cc. of india ink was injected into the left knee joint. There was slight swelling of the knee, but no

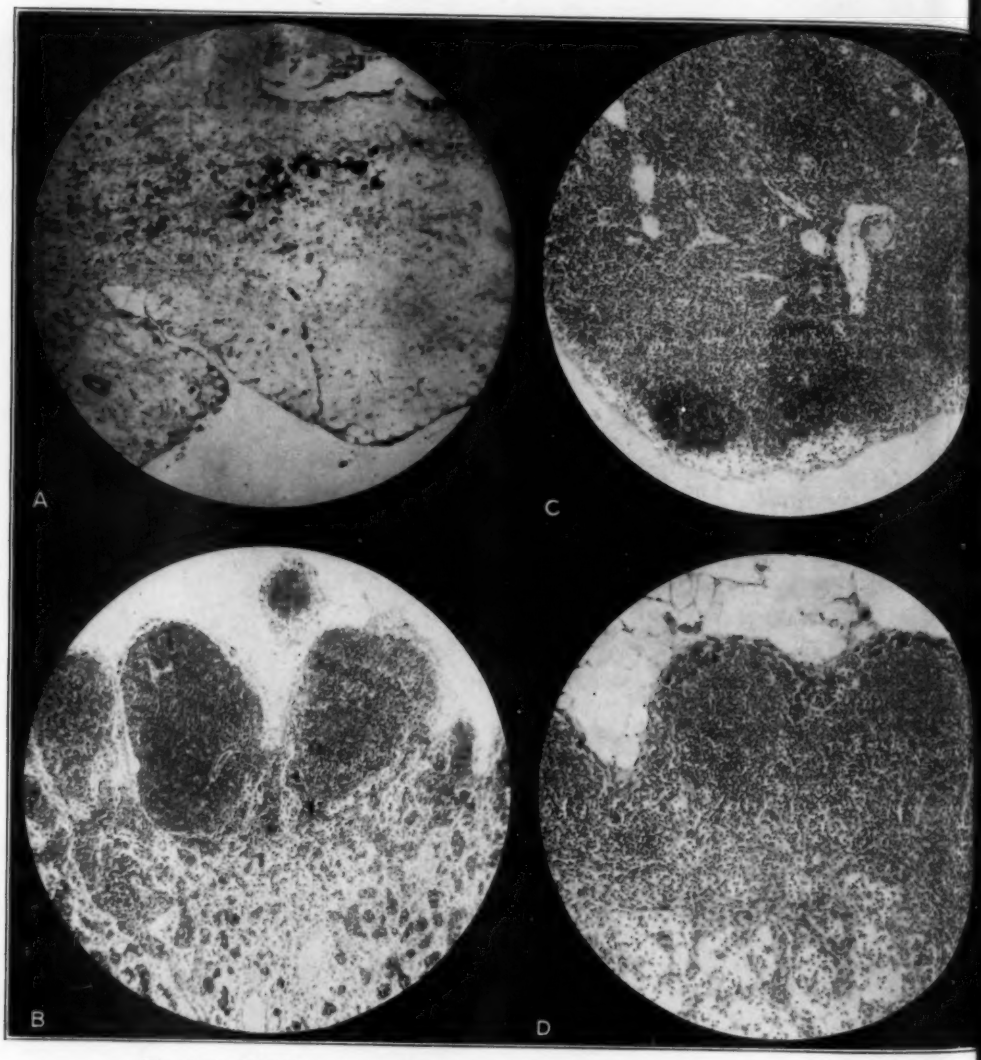

Fig. 2 (rabbit 4).—*A*, portion of joint capsule and fat pad of knee, showing ink in synovial membrane, with some in lymphatic vessels; reduced from × 125; *B*, external iliac lymph node, showing absorption of india ink; reduced from × 80. *C*, popliteal lymph node, which shows no absorption of india ink; × 80. *D*, inguinal lymph node with no india ink; × 80.

noticeable disturbance of function. The animal was killed three days later. No extravasation was seen about the knee joint. There was no evidence of india ink

in the popliteal lymph nodes or the inguinal lymph nodes. No lymphatic vessels were seen. The external and common iliac lymph nodes were deeply stained with ink. Sections were taken from the joint and from the popliteal, inguinal and common iliac lymph nodes for study.

RABBIT 3.—The technic was the same as for rabbit 1; 0.4 cc. of india ink was injected into the left knee joint. There was slight swelling of the knee joint, which passed off in four days. There was no apparent disturbance of function. The animal was killed three days later. There was no extravasation about the joint. The cavity of the joint was stained throughout with india ink. Much india ink still remained in the joint, partly enmeshed in fibrin. The ink was in greatest amount in the quadriceps pouches. There was no evidence of absorption of ink in the popliteal lymph node. Two lymphatic vessels were seen on the surface of the capsule of the joint on the outer side of knee, but these could not be traced farther. The inguinal lymph nodes showed no ink. The external and common iliac lymph nodes were moderately stained with ink. No ink was observed in any more proximal lymph nodes. Sections were taken from the articular capsule and from the popliteal and common iliac lymph nodes for study.

RABBIT 4.—The same technic was used as for rabbit 1; 0.4 cc. of india ink was injected into the right knee joint. There was swelling of the right knee, which was still present when the animal was killed in four days. There was a slight increase in the fluid in the right knee joint. There was slight extravasation of ink on the outer side of the joint. A moderate amount of india ink remained in the knee joint, chiefly in the quadriceps pouches. One lymphatic vessel could be seen going from the posterior aspect of the joint capsule into Hunter's canal. The popliteal lymph nodes showed a little absorption of ink. The external and common iliac lymph nodes showed a moderate absorption of ink. No more proximal lymph nodes showed absorption of ink. Sections were taken from the capsule of the joint and from the popliteal, inguinal and iliac lymph nodes for study.

RABBIT 5.—The technic was the same as for rabbit 1: 0.4 cc. of india ink was injected into the left knee joint. There was a slight swelling of the joint, which lasted for three days. There was no apparent disturbance in function. The animal was killed seven days later. No extravasation of ink was seen about the joint. The knee joint contained a moderate amount of ink, chiefly in the quadriceps pouches. No lymphatic vessels were seen. There was no evidence of absorption of ink in the popliteal lymph nodes or the inguinal lymph nodes. There was a moderate amount of india ink in the external iliac lymph nodes. No ink was found in any more proximal lymph nodes. Sections were taken from the capsule of the joint and from the popliteal, inguinal and external iliac lymph nodes for study.

RABBIT 6.—The technic was the same as for rabbit 1; 0.4 cc. of india ink was injected into the right knee joint. There was a little swelling of the knee joint, which subsided in two days. There was no observable disturbance in function. The rabbit was killed six days later. There was a very slight extravasation into the tissues on the outer side of the knee. The popliteal lymph nodes showed no evidence of absorption of ink. No lymphatic vessels were seen. There was no evidence of india ink in the inguinal lymph nodes. There was a large amount of ink in the external and common iliac lymph nodes. No absorption was seen in any more proximal lymph nodes. Sections were taken from the articular capsule and from the popliteal, inguinal and external iliac nodes for study.

In these animals the drainage of the india ink through the lymphatics could be traced to the external iliac and to the common iliac lymph

nodes (fig. 2). No ink was found in any instance in the inguinal lymph nodes. India ink was found in the popliteal lymph nodes only when there was extensive extravasation. Occasionally lymphatic vessels were seen going from the joint capsule along the geniculate arteries and veins into Hunter's canal. In the articular capsule the india ink was found chiefly on the epithelial surface of the synovial membrane, partly enmeshed in fibrin. Occasional lymph vessels filled with ink-containing phagocytes were seen. Fewer phagocytic cells and ink particles, as well as lymphatic vessels, were seen in the depth of the synovial tissues as one approached their bony or ligamentous attachments. The ink was seen in the lymph nodes in similar arrangement to that described for the ankle joint (fig. 2).

In five rabbits, injections of india ink were made directly into the cavity of the hip joint.

RABBIT 1.—Ether anesthesia was used. The hair was shaved from the right groin, and the area painted with alcohol and with 3 per cent iodine. With a 25 gage needle, 0.25 cc. of india ink was injected into the hip joint just external to the femoral artery after the location of the femoral head had been palpated. A moderate amount of limitation in motion of the hip joint was observed for about two days. The rabbit was killed four days later. There was slight extravasation into the muscles. A small amount of india ink was seen in the hip joint along the side of the femoral neck. No lymphatic vessels were seen. There was no evidence of ink in the inguinal lymph nodes. The common iliac lymph nodes were moderately stained with ink. No ink was observed in any more proximal lymph nodes. Sections were taken from the capsule of the joint and from the inguinal and common iliac lymph nodes for study.

RABBIT 2.—The technic was the same as for rabbit 1; 0.25 cc. of india ink was injected into the right hip joint. No disturbance in the use of the hip joint was seen. The animal was killed six days later. There was slight extravasation of ink in the deep muscles anterior to the hip joint. No lymphatic vessels were seen. No absorption of ink was seen in the inguinal lymph nodes. There was a moderate amount of deposition of ink in the external and common iliac lymph nodes. No ink was seen in any more proximal lymph nodes. Sections were taken from the capsule of the joint and from the inguinal and iliac lymph nodes for microscopic study.

RABBIT 3.—The technic was the same as for rabbit 1; 0.25 cc. of india ink was injected into the right hip joint. No disturbance in the use of the hip joint was seen. The animal was killed six days later. Slight extravasation of ink was seen in the deep muscles anterior to the hip joint. No lymphatic vessels were seen. No absorption of ink was seen in the inguinal lymph nodes. There was a moderate amount of deposition of ink in the external and common iliac lymph nodes. Sections were taken from the capsule of the joint and from the inguinal and iliac lymph nodes for study.

RABBIT 4.—Paraldehyde anesthesia was used. The right gluteal region was shaved and painted with alcohol and iodine. Through the posterior approach to the hip joint described by Ober,[47] the capsule of the hip joint was exposed.

47. Ober, F. R.: Posterior Anthrotomy of the Hip Joint, J. A. M. A. **83**:1500 (Nov. 8) 1924.

Twenty-five hundredths cubic centimeter of india ink was injected into the hip joint. The limitation in the use of the hip joint had not disappeared in five days, when the animal was killed. There was very slight extravasation of ink into the subgluteal fat. A few lymphatic vessels were seen on the posterior aspect of the joint capsule, but they could not be traced farther. No ink was seen in the inguinal lymph nodes. There was moderate staining of the external and common iliac lymph nodes. No more proximal lymph nodes showed any absorption of ink. Sections were taken from the common iliac and the inguinal lymph nodes and from the articular capsule for study.

RABBIT 5.—Paraldehyde anesthesia was given. The technic was the same as for rabbit 4; 0.25 cc. of india ink was injected into the hip joint posteriorly. There was marked limitation of motion in the joint, but no definite swelling could be palpated. The animal was killed in four days. There was slight extravasation of the ink outside of the capsule of the joint. No lymphatic vessels were seen. There was no india ink in the inguinal lymph nodes. There was a moderate amount of ink in the external and common iliac lymph nodes. No ink was found in any more proximal lymph nodes. Tissue was removed from the joint capsule and from the inguinal and the common iliac lymph nodes for microscopic study (fig. 3).

These experiments showed that the lymphatic absorption from the hip joint in the rabbit was through the so-called deep system to the iliac lymph nodes. In no case was there any absorption into the inguinal lymph nodes. The microscopic study of tissue showed the same manner of absorption of india ink as was seen for the knee and ankle joints. The hip joint being so deeply placed and covered by muscles, the slight extravasation that invariably occurred on injection did not lead to any absorption of india ink by the superficial lymph channels.

A number of clinical observations have been recorded, and I have observed a swelling of the superficial inguinal glands in inflammation of the joints of the lower extremity. Usually such swelling was bilateral, and frequently epitrochlear, axillary and cervical lymph nodes were palpable at the same time. As possible explanations for this, extension of the inflammation to superficial tissues or an involvement of the lymph nodes through a generalized infection of the blood stream has been suggested. Both these experiments and the work of others on the human cadaver have offered no other explanation.

While this work was in progress, several observations on lymphatic drainage of joints appeared in the literature. Baum,[48] in 1927, reported lymphatics in the synovial membrane of dogs after the direct injection of dyes. In the foreleg of the horse he traced the lymphatic drainage from the carpal joints to the cubital (epitrochlear) and cervical lymph nodes; from the elbow joint, lymphatic drainage was traced to the cubital and axillary nodes, and from the shoulder joint, the lymphatic

48. Baum, H.: Ztschr. f. d. ges. Anat. (Abt. 1) **84**:192, 1927.

drainage was followed to the axillary, posterior cervical and superficial cervical lymph nodes. At almost the same time Kolodny [49] described the lymphatic drainage of the long bones of the lower extremity after the injection of india ink into dogs. He found that the lymphatic drainage from the bones was entirely through the so-called deep system, to the deep femoral and iliac lymph nodes. In 1929, Smith and Campbell,[50] using berlin blue, a soluble dye, found that the lymphatics were not filled until intra-articular pressure was so great that the joint became greatly distended. They were able to trace lymphatics into Hunter's canal. During the same year, Oschkaderow [51] studied the lymphatics in the interphalangeal joints in cadavers. In these joints he found from three to five lymphatic vessels which joined larger lymphatics along the digital arteries. These lymphatics had no relationship with the fascial spaces of the hand.

Schdanow [52] has recently described the lymphatic drainage of the tarsal, knee and hip joint as observed in the cadavers of stillborn babies. In the tarsal joints he observed lymphatic drainage along the peroneal and anterior tibial vessels to the popliteal lymph node. He did not trace this drainage farther. He found a very complex lymphatic system draining the cavity of the knee joint. The lymphatic radicals were traced along the geniculate vessels into Hunter's canal. He found slight drainage into the popliteal lymph nodes from the posterior and inferior portions of the capsule of the joint. The chief lymphatic absorption, however, was to the deep femoral and iliac lymph nodes. From the cavity of the hip joint he was able to trace lymphatic drainage to the deep femoral and iliac lymph nodes. He observed several very small lymph nodes along the gluteal arteries.

The findings of these investigators were similar to those I found in the rabbit. The lymphatic drainage of joints was found to be through the so-called deep system to the lymph nodes draining this deep system. Job,[53] as well as other students of comparative anatomy, has shown that as a rule the larger and more highly developed animals have more lymph nodes, man having supposedly the greatest number and distribution. In dogs and in man there are femoral nodes draining the deep system, apparently not connected with the inguinal group of lymph nodes. The rabbit does not have deep femoral lymph nodes.

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49. Kolodny, A.: The Relation of the Bone Marrow to the Lymphatic System. Its Rôle in the Spreading of Carcinomatous Metastases Throughout the Skeleton, Arch. Surg. **11**:690 (Nov.) 1925.

50. Smith, M., and Campbell, J. R.: Proc. Soc. Exper. Biol. & Med. **26**:395, 1929.

51. Oschkaderow, W. T.: Anat. Anz. **66**:377, 1929.

52. Schdanow, D. A.: Anat. Anz. **69**:194, 1930.

53. Job, T. T.: Am. J. Anat. **31**:125, 1922.

An attempt was then made to confirm these findings in regard to lymphatic drainage by studying the absorption of bacteria from joint cavities. Tubercle bacilli were chosen as being the most easily demonstrable.

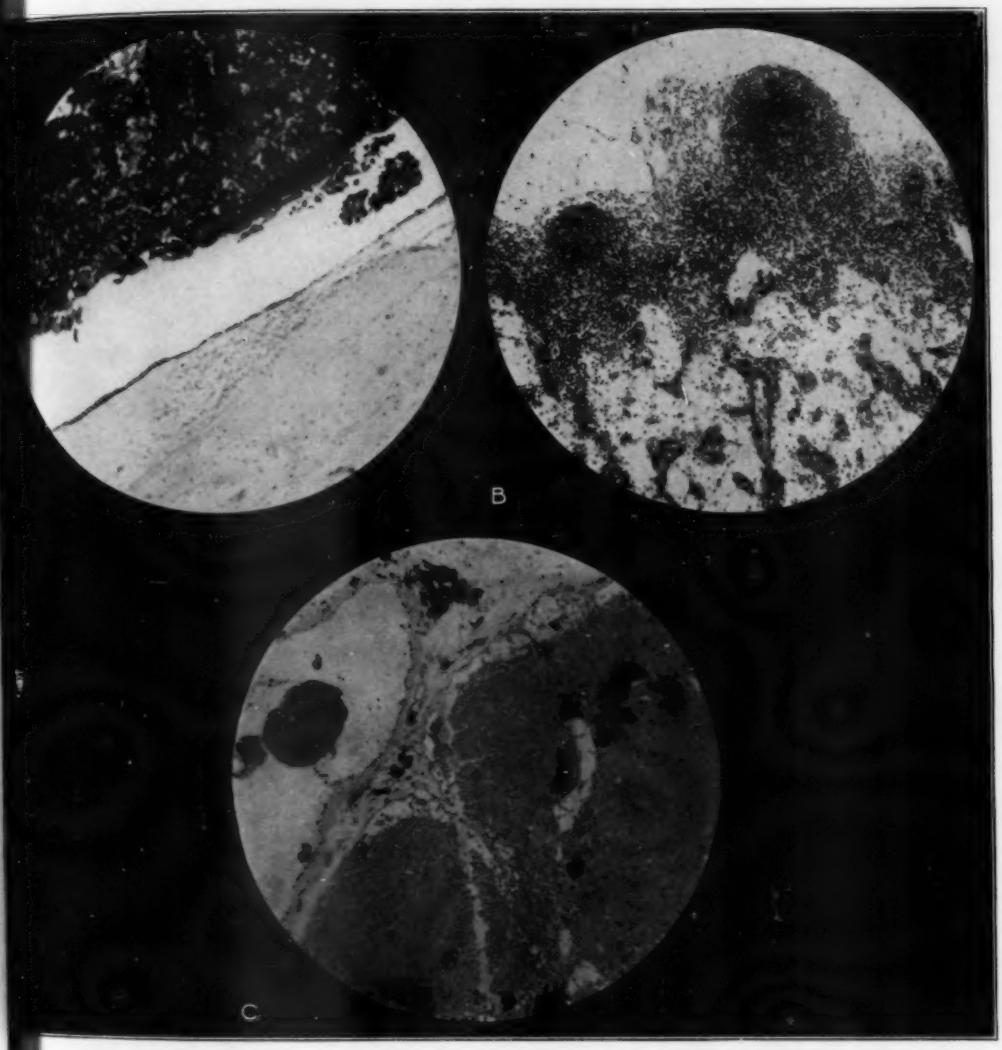

Fig. 3 (rabbit 5).—*A*, india ink in the articular capsule along the neck of the femur; reduced from × 88. *B*, inguinal lymph node, showing two rather dense lymphoid follicles but no ink absorption. *C*, common iliac lymph node, showing a moderate amount of india ink. At the left of the lymph node there is a large mass of ink-containing phagocytes in the afferent lymphatic vessel.

Injections of a freshly autoclaved emulsion of human tubercle bacillus (strain H 37) were made into the knee joints of four rabbits.

Rabbit 1.—Ether anesthesia was used. The skin over the right knee was shaved and painted with alcohol and iodine; 0.3 cc. of an emulsion of human tubercle bacilli (strain H 37), freshly prepared and autoclaved, was injected into the right knee joint. There was a little swelling of the knee joint, which had almost subsided when the animal was killed three days later. There was no increase in joint fluid. No tubercle bacilli were found in smears from the joint fluid. Sections were taken from the capsule of the joint and from the common iliac lymph nodes for microscopic study.

Rabbit 2.—The technic was the same as for rabbit 1; 0.3 cc. of a freshly prepared and autoclaved emulsion of human tubercle bacilli was injected into the left knee joint. There were slight swelling and limitation of motion in the knee joint, which disappeared in three days. The animal was killed five days later. There was a slight increase in the joint fluid. No tubercle bacilli were found in smears from the joint fluid. Sections were taken from the capsule of the joint and from the external iliac lymph nodes for study.

Rabbit 3.—The technic was the same as for rabbit 1; 0.3 cc. of a freshly prepared, autoclaved emulsion of human tubercle bacilli was injected into the left knee joint. There were slight swelling in the knee joint and slight stiffness, which disappeared in two days. The animal was killed eight days later. No tubercle bacilli were found in smears from the synovial fluid. Sections were taken from the capsule of the joint and from the common iliac lymph nodes for microscopic study.

Rabbit 4.—The technic was the same as for rabbit 1; 0.3 cc. of a freshly prepared, autoclaved emulsion of human tubercle bacilli was injected into the right knee joint. There was slight swelling of the joint, which disappeared in three days. There was no obvious disturbance in joint function. The rabbit was killed two weeks later. There was no excess fluid in the joint. No tubercle bacilli were found in smears from the joint fluid. Sections were taken from the articular capsule and from the common iliac lymph nodes for microscopic study.

It was supposed that bacilli would be removed from the joints in the same manner as insoluble particles, particularly if the bacteria did not arouse a violent inflammatory reaction. Numerous workers, using guinea-pigs, had recovered tubercle bacilli from the regional lymph nodes after the injection of tuberculous material. Tubercle bacilli found in tuberculous glands of the neck were traced in some cases to tuberculous tonsils. Herring and MacNaughton,[54] from their studies on lymphatics, came to the conclusion that both particulate matter and tubercle bacilli were removed in the same manner by the lymphatics in the human lung. Consequently, it was surprising to find no tubercle bacilli in the articular capsule and in the external and common iliac lymph nodes in any of the rabbits given injections. Microscopic sections examined by several pathologists showed no tubercle bacilli or early tubercle formation (fig. 4). In sections from the right common iliac lymph node in rabbit 4, there was a moderate area of necrosis. However, it could not be determined whether this was due to the mate-

54. Herring, P. T., and MacNaughton, F. G.: Lancet **1**:1081, 1922.

Fig. 4 (rabbit 4).—*A*, synovial villus and cartilage. There is no evidence of tuberculous disease or of inflammation; × 78. *B*, common iliac lymph node, no tuberculosis; × 90.

rial injected. Because no bacilli were found in the joint tissues or lymphatic system, it was thought that the bovine type of bacilli might give better results, since rabbits are supposed to be relatively resistant to human tubercle bacilli. Again, the autoclaving might have made it possible for the joint and tissue fluids to bring about a more rapid disintegration of the tubercle bacilli.

Consequently, an emulsion of a rapidly growing colony of bovine tubercle bacilli, smears of which showed as many as 20 bacilli per oil immersion field, was injected into the knee joints of two rabbits. This emulsion was not autoclaved.

RABBIT 1.—The technic was the same as for the rabbits of the previous series; 0.3 cc. of a freshly prepared emulsion of living bovine tubercle bacilli was injected into the right knee joint. There were slight swelling and stiffness, which had not subsided when the animal was killed three days later. There was a little increase in joint fluid. Smears from the joint showed no tubercle bacilli. Sections were taken from the joint capsule and from the right common iliac lymph node for study.

RABBIT 2.—The technic was the same as for rabbit 1; 0.3 cc. of a freshly prepared emulsion of living bovine tubercle bacilli was injected into the right knee joint. There was slight swelling, which subsided in two days, but no obvious disturbance of function. The rabbit was killed two weeks later. There was no increase in joint fluid. The joint had the usual macroscopic appearance. No tubercle bacilli were found in the joint fluid. Sections were taken from the joint capsule and from the right common iliac lymph node for microscopic study.

Again, no tubercle bacilli were found either in the articular capsule or in the common iliac lymph nodes. Nor did the capsule of the joint or the lymph nodes show any evidence of a tuberculous infection. The tubercle bacilli that had been injected had disappeared in some inexplicable manner. It was decided to repeat the work. This time the bovine tubercle bacilli were stained in vitro by the Ziehl-Neelsen method, washed, centrifugated and taken up again in salt solution before injection. Samples of the suspension showed as many as 10 tubercle bacilli per oil immersion field. This emulsion was injected into the ankle joint in two rabbits and into the knee joint in two rabbits.

RABBIT 1.—The usual aseptic technic was used; 0.25 cc. of the emulsion of bovine tubercle bacilli which had been stained in vitro was injected into the right ankle joint. The animal was killed four days later. Examination of the ankle joint showed a slight increase in fluid, but no evidence of the injected material. Tissue from the articular capsule and from the right external iliac lymph nodes was removed for microscopic study.

RABBIT 2.—The technic was the same as for rabbit 1; 0.25 cc. of an emulsion of stained bovine tubercle bacilli was injected into the left ankle joint. Except for slight swelling, which disappeared in three days, no local reaction was noted. The animal was killed eight days later. No bacilli were seen in smears from the joint fluid. Tissue was removed from the joint capsule and from the iliac lymph nodes for histologic examination.

RABBIT 3.—The technic was the same as for rabbit 1; 0.5 cc. of an emulsion of stained tubercle bacilli was injected into the left knee joint. There was slight swelling in the joint for three days, but no other joint reaction. The animal was killed eight days later. There was no evidence of tubercle bacilli in the joint. Sections of the articular capsule and the common iliac lymph nodes were removed for microscopic study.

RABBIT 4.—The technic was the same as for rabbit 1; 0.5 cc. of an emulsion of stained bovine tubercle bacilli was injected into the left knee joint. There was slight swelling of the knee, which disappeared in three days. The animal was killed two weeks later. The knee joint showed a slight inflammatory reaction. There was no evidence of tubercle bacilli in the joint fluid. Sections were taken from the joint capsule and from the iliac lymph nodes for microscopic study.

It was thought that the lymphatic absorption of bacilli described by Willis,[55] Miller [3] and Herring and MacNaughton [54] might be observed better by first staining the tubercle bacilli in vitro by the Ziehl-Neelsen method. This technic had been used by a number of investigators working with tuberculosis. Cultures of bovine bacilli grown on Petroff's medium were scraped into a sterile mortar, and an emulsion was made in physiologic solution of sodium chloride. Counts from the emulsion showed from 5 to 50 bacilli in a field. This emulsion was then stained in vitro by the Ziehl-Neelsen method. These emulsions were freshly prepared and injected while fresh. The animals were killed at varying intervals to see whether a prolonged period was necessary for bacillary absorption. In all of these sections, as in the previous experiments with tubercle bacilli, no bacteria were seen, nor did the tissue show evidence of tuberculous infection. In the rabbit, at least, it seemed that other factors were involved which made the absorption of the tubercle bacilli from joint cavities a different matter from the absorption of inorganic particulate matter.

Since lymphatic absorption of bacteria in massive doses had been observed from other serous cavities by a number of investigators, it was thought that repeated doses of tubercle bacilli might make possible the demonstration of the absorption of bacilli in the lymph nodes. Repeated injections might either stimulate more efficient absorption or break down any protective mechanism, if such existed, against bacillary absorption. A fresh emulsion of a relatively avirulent strain of human tubercle bacilli in physiologic solution of sodium chloride was used. Four rabbits were given injections at varying intervals.

RABBIT 1.—Ether anesthesia was used. The hair was shaved over the right knee joint. With the usual aseptic technic, 0.25 cc. of the fresh human tubercle bacilli emulsion was injected into the right knee joint. There was practically no reaction. The knee was not appreciably swollen. Two days later, and at intervals of two days, the injection of tubercle bacilli was repeated until four injections had been given. After the second injection the knee became markedly swollen, warm

55. Willis, H. S.: Am. Rev. Tuberc. **11**:427, 1925.

and limited in motion. Swelling persisted unchanged until the animal was killed two days after the last injection. The knee contained a large amount of seropurulent fluid, which showed a number of tubercle bacilli in smears. The cartilage was a dull brownish gray; the articular capsule was thickened and injected. Smears from the common iliac lymph nodes, which were moderately enlarged, showed tubercle bacilli. Tissue was removed from the knee joint and from the common iliac nodes for microscopic study.

Rabbit 2.—The technic was the same as for rabbit 1; 0.3 cc. of a fresh emulsion of human tubercle bacilli was injected into the right knee joint. There was a slight swelling of the articular tissues, which lasted until the rabbit was killed. There was no observable limitation in motion. Injections were made every four days until four injections had been given. The animal was killed four days after the last injection. Smears from the joint fluid showed no bacteria. There was no definite vascular congestion of the articular capsule. The capsule of the joint was a little thickened. There was no erosion of the articular cartilage. The iliac lymph nodes were much enlarged. A smear from the right common lymph node showed tubercle bacilli. Sections of tissue were removed from the capsule of the joint and from the right common iliac lymph node for microscopic study.

Rabbit 3.—The technic was the same as for rabbit 1; 0.3 cc. of a fresh emulsion of human tubercle bacilli was injected into the left knee joint. There were slight swelling and slight limitation of motion in the knee, which persisted until the animal was killed. The injections of tubercle bacilli were repeated every eight days until four injections had been given. The animal was killed one week after the last injection. There was a moderate amount of seropurulent fluid in the knee joint, which showed no tubercle bacilli or smears. There were moderate hyperemia and edema of the synovial membrane. The cartilage had lost its glistening white color and was slightly eroded. The common iliac lymph nodes were enlarged, but showed no tubercle bacilli in smears taken from the incised lymph node. Sections of tissue were taken from the capsule of the joint and from the common iliac lymph nodes for microscopic study (fig. 5).

Rabbit 4.—The technic was the same as for rabbit 1; 0.3 cc. of a fresh emulsion of human tubercle bacilli was injected into the right knee joint. Injections were repeated every two weeks until four injections were given. The rabbit was killed ten days after the last injection. There was moderate swelling of the knee, which persisted from the first injection until the animal was killed, but there was no disturbance in function. When the knee joint was opened, a moderate increase of cloudy fluid was found. No tubercle bacilli were seen in smears. The synovial membrane was thickened; the cartilage was dull in color and showed slight superficial erosion. Sections of tissue were taken from the capsule of the joint and from the common iliac lymph node for microscopic study.

The microscopic study of the capsule and of the joints of the lymph nodes in rabbits 3 and 4 showed tuberculous inflammation. In rabbit 1, tubercle bacilli were recovered from the synovial fluid and from a swollen, common iliac lymph node (fig. 5). In rabbit 2, tubercle bacilli were found in a smear from the common iliac lymph node. The tissues from the joint and from the lymph nodes in rabbits 1 and 2 did not show definite tuberculous inflammation. Repeated injections of tubercle bacilli into the joint cavities of rabbits showed the lymphatic absorption of these bacteria to be the same as that observed for particulate matter.

Fig. 5.—*A*, synovial membrane from the left knee joint, showing at top the serous surface of the membrane; × 340. There are numerous epitheloid cells, but no definite tubercle formation. *B*, common iliac lymph node, with epitheloid cells and beginning tubercle formation; × 425.

Other factors, probably chiefly chemical, played a part which made the absorption of tubercle bacilli less readily demonstrable than that of chemically inert particles. Cunningham,[56] Hetherington [57] and Wright [58] have described the tissue reactions which occur in tuberculous infection and after the injection of nontuberculous substances. They found that the characteristic cells of tuberculous tissue could be produced by a number of mildly irritating substances varying in chemical nature, particularly organic substances, of which macerated rabbit brain was the best. However, these authors, while noting relative differences in the time and intensity of the tissue reaction, offered no explanation for any difference in lymphatic physiology in the absorption of various organic and inorganic substances.

The mechanism involved in the removal of particulate matter from tissues and serous cavities has been the subject of controversy since the description by Beck [59] in 1893 of what he termed stomas in the lymphatic vessels. In 1903, MacCallum [60] offered evidence to show that the lymphatic system was a closed system without stomas, confirming the earlier findings of Kolossow [61] and Muscatello.[62] Bolton [63] and von Recklinghausen [64] observed the presence of particulate matter in the lymphatic vessels of the diaphragm several minutes after intraperitoneal injection, too soon, they supposed, for phagocytosis, since examination showed that the particles were free in the lymphatic vessels. Higgins and Lemon [65] observed powdered graphite in the diaphragmatic lymphatics four minutes after intraperitoneal injection.

Filling of the lymphatics of the capsule of the knee joint with colored solutions of dyes has been recorded by Teichmann [4] and by Smith and Campbell,[50] but in these instances the joint cavity was overexpanded before any filling of the lymphatics was observed. In such cases rupture into the lymphatics could easily have occurred. In the lymphatics of the diaphragm, Bolton [63] felt that the contraction of the diaphragm with alterations in intra-abdominal pressure supplied the force for the flow of fluid into the lymphatics. Drinker and Field [34] have noticed graphite

56. Cunningham, R. S.: Tubercle **12**:404, 1931.

57. Hetherington, D. C.: Proc. Soc. Exper. Biol. & Med. **26**:333, 1929.

58. Wright, A. W.: Am. J. Path. **6**:87, 1930.

59. Beck: Wien. klin. Wchnschr. **6**:823, 1893.

60. MacCallum, W. G.: Anat. Anz. **23**:157, 1903; Arch. f. Anat. u. Entwcklngsgesch., 1902, p. 273.

61. Kolossow, A.: Arch. f. mikr. Anat. **42**:318, 1893.

62. Muscatello, G.: Virchows Arch. f. path. Anat. **142**:327, 1895.

63. Bolton, C.: J. Path. & Bact. **24**:429, 1921.

64. von Recklinghausen: Die Lymphgefässe und ihre Beziehung zum Bindegewebe, Berlin, A. Hirschwald, 1862; Virchows Arch. f. path. Anat. **24**:172, 1863.

65. Higgins, G. W., and Lemon, W. S.: Am. J. M. Sc. **178**:536, 1929.

particles in the subcutaneous lymphatics five minutes after their injection into the subcutaneous tissues when the animal was active. They concluded that motion or massage caused the lymphatic vessels to lose their anatomic integrity and to become momentarily open into the tissue spaces. Practically all modern study has tended to disprove the presence of stomas or constant openings of any sort into lymphatic vessels. In microscopic sections from rabbits' joints, particles were often seen in the interstices and beneath the lining synovial cells, apparently free in the tissues. The work of Rynearson [66] and Cunningham [67] on this problem has suggested a fairly loose union of the lining cells, so that mechanically small particles might pass between the lining cells and readily lodge in the tissues beneath.

The cells that play the chief rôle in phagocytosis of particles in serous cavities are the endothelial cells of the reticulo-endothelial system. Their origin has not been definitely established (Cunningham [67]). Their presence in normal, circulating lymph has been denied (Kindwall [68]). Gay,[69] who has studied the problem of the origin of these phagocytic cells in relation to tissue resistance, believed that these phagocytic cells of serous cavities, the histiocytes, come from the clasmatocytes of connective tissue. Phagocytosis by such cells is the chief method, probably the only method, with present histologic and physiolgic understanding, by which particles larger than molecular size enter the lymphatics. Clark [70] has described the phagocytosis of fat droplets in the tails of tadpoles by cells which then entered the lymphatic vessels. The wide potential spaces between the cells of the lymphatic vessel wall and the arrangement of the cells like tiles on a roof have been suggested by Muscatello [62] as a provision for the easy entrance of phagocytic cells into the lymphatic vessels.

Material larger than molecular size is taken up from the tissues by blood vessels only under unusual conditions, if at all. Krogh [71] has mentioned the possibility of such absorption where the blood vessels are extremely dilated, but no observation of such occurrence is on record. W. J. Mayo [72] stated that except in the gastro-intestinal tract the blood vessels are impervious to particulate matter and colloidal substances.

66. Rynearson, E. H.: J. Bone & Joint Surg. **13**:127, 1931.

67. Cunningham, R. S.: Physiol. Rev. **6**:242, 1926.

68. Kindwall, J. A.: Bull. Johns Hopkins Hosp. **40**:39, 1927.

69. Gay, F. P.: Tissue Resistance and Immunity, J. A. M. A. **97**:1193 (Oct. 24) 1931.

70. Clark, E. R.: Am. J. Anat. **21**:421, 1916.

71. Krogh, August: The Anatomy and Physiology of Capillaries, New Haven, Conn., Yale University Press, 1922.

72. Mayo, W. J.: The Significance of Lymphatic Involvement in Infections, J. A. M. A. **80**:221 (Jan. 27) 1923.

Katsura,[73] working on the absorption of dyes from the pleural and peritoneal cavities of dogs and rabbits, found that crystalloid stains are absorbed rapidly through the blood stream, while colloidal stains are absorbed more slowly through the lymphatics. In rabbits, I observed complete absorption of soluble dyes, such as methylene blue (methylthionine chloride, U. S. P.) or carmine, twenty-four hours after their injection into joint cavities. There was usually staining of the entire joint capsule, but no trace of soluble dye could be seen in the lymph nodes draining that joint cavity. Nonsoluble dyes, particulate matter or colloidal, such as india ink, were absorbed much more slowly, some dye remaining ensheathed in fibrin or fibrous tissue within the articular cavity often for months after its injection. During the time, in animals killed at lengthening intervals, a gradually increasing accumulation of the dye was seen in the lymph nodes draining those tissues.

Herring and MacNaughton,[54] in making investigations on the absorption of particulate matter from the lungs, concluded that both india ink and the tubercle bacillus were taken up in the same manner by phagocytes and carried to the lymphatics in the human lung. This was also found to be true in the joint cavity of rabbits, although bacteria were not demonstrable with the same regularity as particulate matter. In studying the removal of colloidal and particulate carbon from the knee joint in rabbits, Key [35] concluded that most of the injected material was carried by macrophages to lymphatic capillaries. When the macrophages died, the particulate matter that they were transporting was picked up and carried by succeeding generations of phagocytes. The particles were found first in lymph nodes and later in the liver, spleen and bone marrow. Rynearson [66] found that particles from joint cavities lodged in all tissues of the reticulo-endothelium system.

Job [53] and Herring and MacNaughton [54] found that the lymph sinuses of the first proximal lymph node draining the area studied acted as efficient filters for the material brought to them by the phagocytic cells. They believed that material was carried only to more proximal lymph nodes, through the lymphatic anastomoses around the lymph node, when it came in too large quantities to be taken care of adequately by the first lymph node reached. No lymphatics have been found unconnected with lymph nodes. In my study of the drainage of the joints of the lower extremity, no india ink was ever seen in lymph nodes above those along the lumbar spine, nor was any found in the anterior mediastinal lymph nodes. The work of Poyneter [74] gave a possible explanation for this. From his experiments he concluded that the lymphatic drainage from the lower extremity passed through the anterior mediasti-

73. Katsura, S.: Tohoku J. Exper. Med. **5**:263, 1924.

74. Poyneter, C. W. M.: Colorado Med. **23**:386, 1926.

nal lymphatics and not through the thoracic duct. He found that the thoracic duct drained only the peritoneal and pleural cavities.

In the beginning of this study, dyes mixed with irritating substances, such as ether and turpentine, as advocated by Gerota,[9] were injected into the joints of living animals. The studies had to be given up, because there was very little absorption from the articular cavities, with practically no deposition of the dye in the lymph nodes. At the same time a violent inflammation was produced in the joint, which subsided in one or two weeks. This led to the conclusion that the inflammation had in some way hindered the mechanism of absorption through the lymphatics. Notkin[75] was able to impede absorption from the peritoneal cavity in dogs by the intraperitoneal injection of irritating substances. He determined the average time required for the appearance of hemoglobin or india ink in the lymph of the thoracic duct after intraperitoneal injection into normal dogs. After he had produced a peritoneal inflammation by the intraperitoneal injection of a solution of potassium iodide, he found that the time required for the first appearance of the hemoglobin or india ink after intraperitoneal injection was about three times as great as in normal dogs. Microscopic studies of the central tendon of the diaphragm, after injections of potassium iodide, showed most of the lymphatics shrunken and many of them obliterated, where normally a rich plexus of lymphatic vessels was found.

These observations led to further study of lymphatic absorption from joint cavities after the production of a synovitis. After the trial of a large number of substances, a 20 per cent solution of potassium iodide was found to be most satisfactory. The local pharmacologic action of this drug has recently been described by Cameron.[76] In single injections into joint cavities, it produced a mild inflammation, but rarely any serious damage to any articular structures. Injections of 0.5 cc. were made into the knee joints of rabbits; 0.25 cc. was injected when the elbow joint was used. Such injections produced an inflammatory exudate within the joint cavity within from six to twelve hours after injection. The knee or elbow became moderately swollen, but there was no appreciable increase in surface temperature, and there was no apparent limitation in active or passive motion in the joint into which the injection was made. The swelling of the joint lasted usually from two to five days and then subsided. Repeated injections produced the same effect, with a little slower subsidence of subsequent exudations. Within two or three weeks a definite thickening of the joint capsule could be felt in most of the animals. Smears of the joint exudate showed polymorphonuclear cells, lymphocytes and a rather small number

75. Notkin, J. A.: Virchows Arch. f. path. Anat. **225**:47, 1925.

76. Cameron, D. F.: A Comparative Study of Sodium Iodid as an Opaque Medium in Pyelography, Arch. Surg. **1**:184 (July) 1920.

of large mononuclear cells, some containing injected polymorphonuclear cells (Higgins and Lemon [65]).

In five rabbits a single injection of a 20 per cent solution of potassium iodide was made into the knee joint. The animals were killed at varying intervals to determine the extent and duration of tissue changes as well as the effect on the local lymphatics and their absorptive function. The synovial lymphatics were studied by several methods. Thin sheets of synovial membrane were treated with hydrogen dioxide. By this method lymphatics in the depths of the tissue were never demonstrated, nor were the lymphatics shown well in fixed sections. Injections of particulate matter gave data of a decreased function. Injections of india ink given a day or longer before the animal was killed gave suggestive information of the rate of lymphatic absorption. Injections of a 0.5 to 1 per cent solution of mild silver protein into the joint cavity several hours before the animal was killed gave an even more satisfactory demonstration of the lymphatics than was obtained with hydrogen dioxide, with the added advantage that it could be shown better in fixed sections.

RABBIT 1.—Ether anesthesia was used. The hair was shaved over the right knee joint. The skin was painted with alcohol and with 3 per cent iodine. With a 25 gage needle, 0.5 cc. of a 20 per cent solution of potassium iodide was injected into the knee joint. The joint was moderately swollen the following day. The swelling subsided in two days. The animal was killed after three days. There was a moderate increase of turbid fluid in the knee joint. The cartilage was dull, instead of the usual glistening white. The synovial membrane appeared normal. Sections were taken from the synovial membrane of both knee joints for study immediately with hydrogen dioxide. Tissue was also removed from both knee joints for microscopic study.

RABBIT 2.—The technic was the same as for rabbit 1; 0.5 cc. of a 20 per cent solution of potassium iodide was injected into the right knee joint. There was moderate swelling of the knee joint, which subsided in four days. The animal was killed five days after receiving the injection. The cartilage was dull instead of the usual glistening white. There was no increase of fluid in the joint cavity. The synovial membrane appeared normal. Sections were taken from the synovial membrane of both knees for microscopic study. Small pieces of the synovial membrane of both knees were treated with hydrogen dioxide and studied immediately for lymphatics.

RABBIT 3.—The technic was the same as for rabbit 1; 0.5 cc. of a 20 per cent solution of potassium iodide was injected into the left knee joint. There was slight swelling of the joint, which subsided in two days. The animal was killed in one week. No increased amount of fluid was seen in the knee joint. The cartilage and synovial membrane appeared normal. Sections were taken from the synovial membrane for study. Sections from the synovial membrane of both knees were treated immediately with hydrogen dioxide and examined under the microscope for lymphatic vessels.

RABBIT 4.—The technic was the same as for rabbit 1; 0.5 cc. of a 20 per cent solution of potassium iodide was injected into the right knee joint. There was slight swelling of the joint, which subsided in three days. Four days after

injection, 0.4 cc. of a 0.5 per cent solution of mild silver protein (argento-proteinum mite, U. S. P.) was injected into both knees. Four hours after the injection of the silver protein, the animal was killed. Sections of the synovial membrane of the two knees were taken for later microscopic study, and other sections were studied immediately with transmitted light under the microscope.

RABBIT 5.—The technic was the same as for rabbit 1; 0.5 cc. of a 20 per cent solution of potassium iodide was injected into the left knee joint. There was slight swelling of the left knee, which subsided in three days. Six days after injection 0.4 cc. of a 0.5 per cent solution of mild silver protein was injected into the joints of both knees. The rabbit was killed five hours later. Sections were taken from the synovial membrane of both knees, and the lymphatics were studied immediately. Other sections were taken for fixed microscopic preparations.

It was hoped that by the injection of a solution of potassium iodide a mild inflammatory process would be initiated and eventually a mild arthritis produced. Such attempts had been made by Key [77] and Rynearson [66] with various substances. After injections of potassium iodide, there was an exudation of fluid into the joint, and there were slight proliferation of the synovial membrane and dilatation of the blood vessels (fig. 6). The pathologic picture was similar to that described by Key [77] in early experimental arthritis. In all animals that were permitted to live longer than one week, the synovial membrane appeared normal. Examination of the lymphatics with hydrogen dioxide in rabbit 1 showed a decrease in the number of lymphatic vessels in comparison with the number seen in normal synovial membrane. At the same time, the lymphatic vessels that were present were larger than those seen in synovial tissue from the normal joint. A similar but less marked condition was observed in the lymphatics of rabbit 2. In rabbit 3, no difference could be made out between the lymphatics on the two sides. This was probably due to the fact that the joint had wholly recovered from the mild inflammatory reaction produced by the solution of potassium iodide. In rabbits 4 and 5, into the knee joints of which a diluted suspension of colloidal silver was injected a few hours before the animal was killed, the lymphatic vessels were stained a yellowish brown from the absorption of the colloidal silver, and they could be demonstrated more readily than when hydrogen dioxide was used. In rabbit 4, the lymphatic vessels were larger but less in number than those seen in the knee not receiving an injection. In rabbit 5, no difference could be seen between the lymphatics from the synovial membrane of the right and the left knee joints. The inflammatory reaction had subsided, and the lymphatics had apparently recovered from any injury they had suffered.

Since the inflammatory reaction in the knee joint after one injection of potassium iodide was of such a short duration, several injections of

77. Key, J. A.: J. Bone & Joint Surg. **11**:705, 1929.

potassium iodide were given at weekly intervals in an attempt to produce a more lasting change in the lymphatics. Five rabbits were given two injections of potassium iodide at weekly intervals.

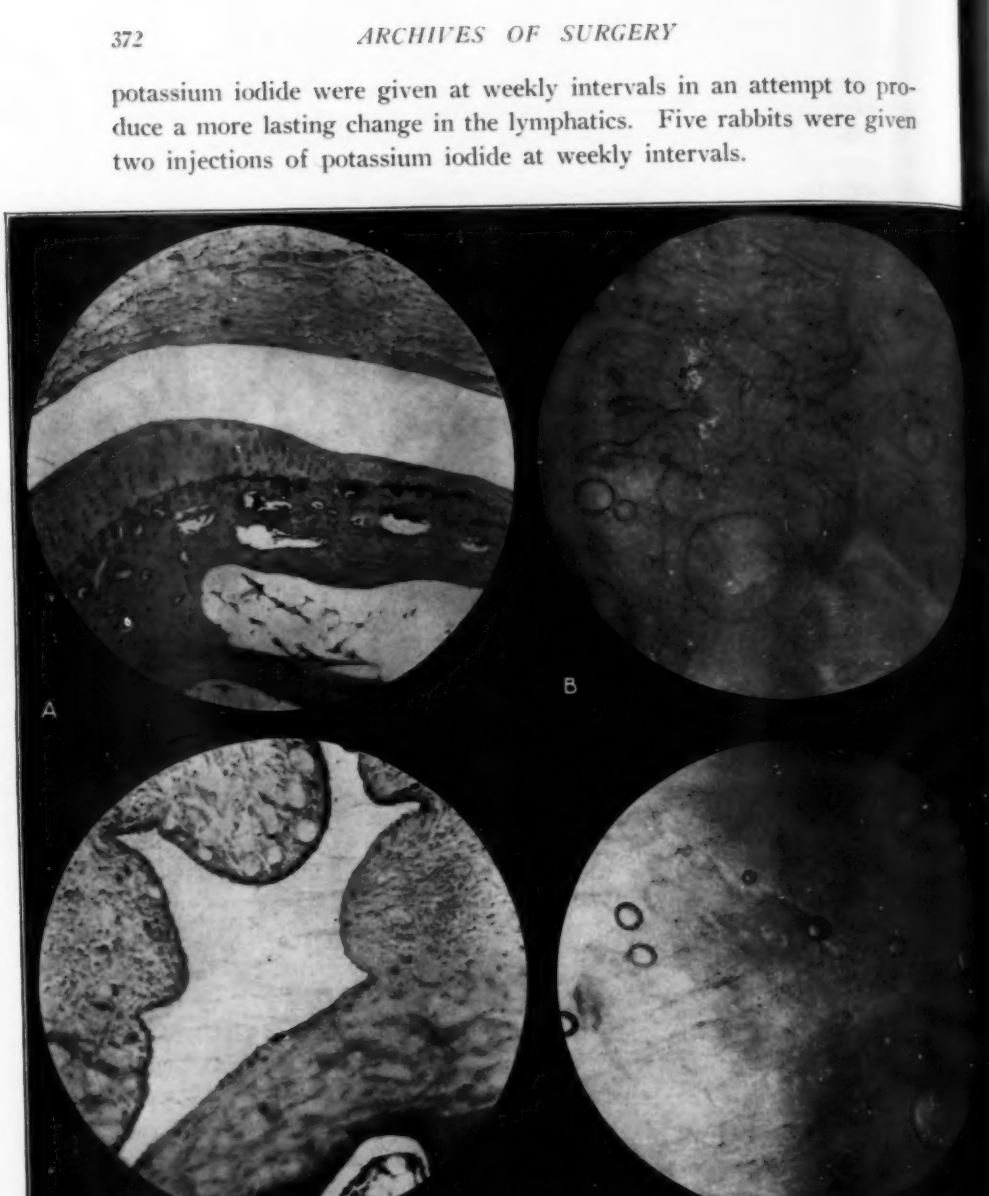

Fig. 6 (rabbit 1).—*A*, synovial membrane of the (uninjected) left knee joint; reduced from × 70. *B*, same as *A*, treated with hydrogen dioxide, showing the superficial lymphatic vessels; reduced from × 80. *C*, synovial membrane of (injected) right knee joint, showing slight vascular congestion, edema and endothelial proliferation; reduced from × 90. *D*, same as *C*, treated with hydrogen dioxide. There are fewer and shorter lymphatic vessels; reduced from × 80.

RABBIT 1.—With the usual aseptic technic, 0.5 cc. of a 20 per cent solution of potassium iodide was injected into the right knee joint. There was moderate swelling of the knee, which subsided in three days. Seven days after the first injection, a second injection of 0.5 cc. of a 20 per cent solution of potassium iodide was made into the same joint.

Following this injection, a moderate swelling appeared which persisted until the animal was killed five days after the last injection. There was a little thickening of the synovial membrane, with projecting, thickened, villus-like processes. The synovial membrane was a deeper red than that on the side on which no injection was made. The cartilage was dull gray and not glistening. Sections from the synovial membrane were treated with hydrogen dioxide and studied under the microscope. On the side into which an injection was made, only an occasional short lymphatic vessel was seen, while a fairly numerous distribution of lymphatics was observed in the synovial membrane on the side not receiving an injection. Sections were taken from both knees for microscopic study.

RABBIT 2.—The same technic was used as for rabbit 1; 0.5 cc. of a 20 per cent solution of potassium iodide was injected into the right knee joint. There was slight swelling of the joint, but no disturbance of function. Swelling disappeared in two days. Six days later a second injection was given. The knee remained swollen for five days. The animal was killed on the seventh day after the last injection. There was no increase of fluid in the knee joint. The synovial membrane showed moderate vascular congestion. The synovial membrane from the knee that had received injections was also thicker. The cartilage was not eroded, but had lost its glistening white appearance. Small sections from the synovial membrane of both knees were treated immediately with hydrogen dioxide. On the side receiving the injection only, one short but rather thick lymphatic vessel was found. A moderate number of small lymphatic vessels were seen in tissue from the side into which no injection was made. Sections were taken from both knees for microscopic study.

RABBIT 3.—The technic was the same as for rabbit 1, except that the joints of the foreleg (humero-ulnar), as well as the joints of the knee, were used. Five-tenths cubic centimeter of a 20 per cent solution of potassium iodide was injected into the right knee joint, and 0.25 cc. into the joint of the right foreleg. There was a slight swelling which disappeared in both joints by the third day. A second injection of like amount was made into both the knee joint and the foreleg joint on the seventh day. The swelling persisted in the foreleg joint for five days, and had not disappeared from the knee joint when the animal was killed on the fourteenth day after the last injection. Four hours before the animal was killed, 0.4 cc. of a 1 per cent solution of mild silver protein was injected into both knee joints, and 0.2 cc. was injected into the joints of both forelegs. At autopsy, there was a little increase in the fluid in all four joints. The synovial membrane was thicker in the right knee joint and right foreleg joint and showed moderate vascular congestion. The cartilage was not eroded, but appeared dull gray on the right side, and white and glistening on the left side. The sections of tissue from the synovial membrane were studied immediately under the microscope with transmitted light. On the right side, the sections from the knee and foreleg were similar. They showed only an occasional large lymphatic vessel. On the left side, a fairly extensive plexus of small lymphatic vessels was observed in tissue from the joints of both the knees and the forelegs. Sections were taken from the four joints for further study.

Rabbit 4.—The procedure was the same as for rabbit 3. After the first injection of potassium iodide, there was slight swelling in both joints receiving injection, which persisted to the second injection on the sixth day. Following the second injection, there was moderate swelling, but no appreciable limitation in motion, which lasted until the animal was killed on the fourteenth day after the first injection. One day before the animal was killed, 0.4 cc. of india ink, diluted with equal parts of distilled water, was injected into both knee joints. Three hours before the animal was killed, 0.2 cc. of 1 per cent solution of mild silver protein was injected into the joints of both forelegs. When the joints of both knees were opened, it was seen that the joint cavity of the right knee appeared to contain much more ink than that of the left knee. The synovial membrane was thicker and seemed to be more congested on the right side. Sections were taken from the joints of both forelegs and studied immediately with the microscope. On the right side, only a few short lymphatics were seen; on the left, there was an extensive plexus of lymphatic vessels. Sections were taken from the four joints and the regional lymph nodes for microscopic study.

Rabbit 5.—The same procedures were carried out as for rabbit 3. After the first injection into the right side, there was moderate swelling in both joints, which lasted three days. On the seventh day, the injection was repeated. The swelling subsided in five days in the joint of the right foreleg and in six days in the joint of the right knee. The animal was killed eighteen days after the beginning of the experiment. One day before the animal was killed, 0.4 cc. of india ink, diluted with equal parts of distilled water, was injected into both knee joints and 0.2 cc. into both foreleg joints. The synovial membrane in the right knee and the right foreleg was a little thicker and seemed to have more india ink on its surface than the synovial membrane from the joints on the left side. Sections were taken from both knee joints and both foreleg joints for immediate study of the lymphatics with hydrogen dioxide. No appreciable difference could be determined between the lymphatics on the side into which an injection was made and the other side. Tissue was also removed from both knee and both elbow joints for histologic study.

In another series of five rabbits, three weekly injections of potassium iodide were given. The same procedures were carried out as described in the last series. Since the findings were similar in all, only the noteworthy features in each animal will be mentioned. The microscopic observations in both series will be described together.

Rabbit 1.—The procedure was the same as in the last series of rabbits. After the first injection, there was swelling which persisted in both the right foreleg and the right knee joints until the animal was killed one week after the last injection. There was a moderate increase in cloudy fluid in both of the joints into which injections had been made. The synovial membrane was thickened and edematous and was moderately engorged with blood. The cartilages were a dull brownish gray, but no erosion was evident. Sections from the knee and foreleg were studied immediately with hydrogen dioxide. No lymphatics could be demonstrated in the synovial tissue from the right knee and right elbow, while a moderate number of lymphatics could be seen in tissues of the synovial membrane from the left knee and left foreleg joints. Tissues from both knee joints and both foreleg joints were removed for later microscopic study.

Rabbit 2.—In this rabbit swelling of the right knee joint and right foreleg joint lasted three days after the first injection, and, after the second injection,

remained practically unchanged until the animal was killed one week after the last injection. There was no demonstrable disturbance in function. When the right knee and foreleg joints were opened, there was a moderate amount of thin, turbid fluid. The synovial membrane showed venous congestion and was moderately thickened. There were a number of thickened villus-like projections about the margins. The cartilage showed no erosion, but was a dull grayish brown. Sections of the synovial membrane treated with hydrogen dioxide showed an occasional short lymphatic vessel on the right, while there was a fairly abundant plexus of small lymphatic vessels on the left. Sections were taken from the four joints for microscopic section.

Rabbit 3.—After the first injection into the right knee and elbow joints, there was a moderate amount of swelling in both of the joints, with limitation of motion in the right knee, which lasted until the animal was killed six days after the last injection. Into both knee joints and both foreleg joints a 1 per cent solution of mild silver protein was injected four hours before the animal was killed. Sections of the synovial membrane studied immediately showed few lymphatic vessels on the right, while numerous lymphatic vessels were seen in the synovial tissue on the left side. Synovial membrane from both knee joints and both foreleg joints was removed for histologic study.

Rabbit 4.—There was moderate swelling after the first injection, which lasted four days. Swelling persisted after the second injection into the right knee and elbow joints on both sides, with a little disturbance in function in the knee joint and elbow joint until the animals were killed six days after the last injection. A 1 per cent solution of mild silver protein was injected into both knee joints and both elbow joints four hours before the animal was killed. The joints on the right showed findings similar to those already described in the series. Sections from the the synovial membranes studied immediately showed only an occasional short segment of a lymphatic vessel on the right, while there were numerous small lymphatics in the synovial tissue taken from the left knee and elbow joints.

In this animal, there were rather marked and persistent swelling and a little limitation of motion in both the knee joint and the elbow joint from the first injection until the animal was killed six days after the last injection. Two days before the animal was killed, 0.4 cc. of india ink was injected into both knee joints, and 0.2 cc. or india ink was injected into both elbow joints. When the joints were opened, there was apparently moderate absorption of the india ink on the left side, while there was no evidence of absorption of the india ink on the right side, and there was no visible deposition of the india ink in the regional lymph nodes on the right side, while the regional lymph nodes on the left side were deeply stained. Tissues were taken for microscopic study.

The microscopic sections from these two series were similar (fig. 7). The joints that had received three injections of potassium iodide as a rule showed more inflammatory changes than the joints that had received two injections. There was increased proliferation of the synovial membrane with occasional lymphocytic infiltration about the blood vessels. There was a little increase in the number of fibroblasts and in the fibrous tissue in the subserous layer of the synovial membrane, with lymphocytic infiltration occasionally about the blood vessels. The cartilage in a few sections showed necrosis of the superficial cartilage cells, with slight erosion of the surface, but, as a rule, there were

no changes observable in the cartilage. The bone and marrow cavity showed nothing unusual. It was possible only occasionally to demonstrate the silver protein or india ink in the lymphatics in microscopic

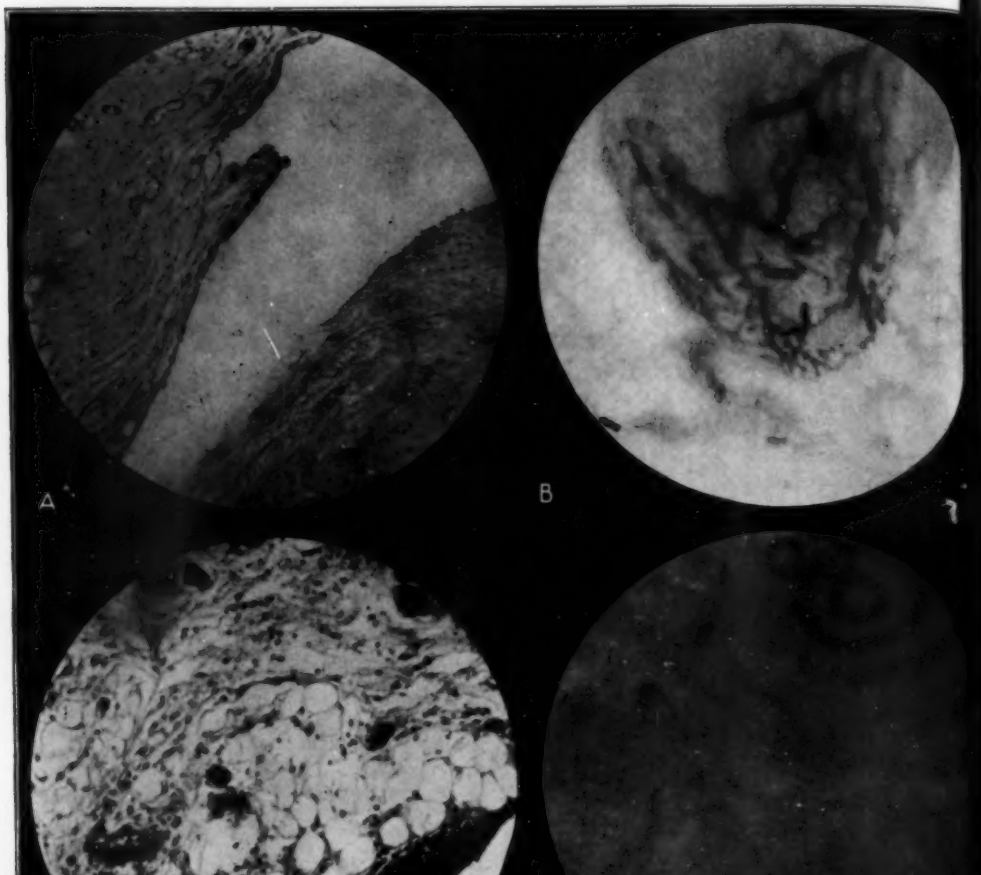

Fig. 7 (rabbit 3).—*A*, synovial membrane of (uninjected) left knee joint. There is very little silver in or on the synovial membrane; reduced from × 80. *B*, same as *A* (fresh tissue). The lymphatic vessels are filled with silver-containing phagocytes; reduced from × 80. *C*, synovial membrane of (injected) right knee joint, showing silver particles chiefly on the synovial surface, edema of tissues, vascular engorgement and endothelial proliferation; reduced from × 90. *D*, same as *C* (fresh tissue); a few silver-stained lymphatics are visible.

sections, although the lymphatic vessels filled with silver protein could be traced fairly easily in fresh tissue. In a few, where they were cut across transversely, they could be definitely identified, and the sections were in practically all cases from the synovial membrane of joints not receiving injections. In the tissues from the joints into which injections of potassium iodide, india ink and, to a less extent, the silver protein were made, the substance was seen either in phagocytic cells or enmeshed in fibrin, for the most part on the surface of the synovial membrane.

The investigations of Rynearson [66] and Key [35] suggested that practically all particulate matter was carried by macrophages to the lymphatic vessels. While particles might be forced mechanically between a rather loose syncytium of synovial cells, penetration of particles to any appreciable depth into the synovial tissue was impossible without the action of phagocytic cells. The recent work of Sigurdson [78] has shown that no openings or stomas were demonstrable on the surface of the synovial membrane. Where absorption of particulate matter did not occur in the experiments recorded in this paper, there were two possible causes. The material was not picked up by macrophages, or the lymphatics were changed, so that the entrance of phagocytes was prevented. Absence or nonactivity of phagocytic cells has been observed in a number of diseases, but discussion of these is beyond the scope of this paper. In the microscopic sections phagocytic cells filled with particulate matter were observed in large numbers on the serous surface of the synovial membrane, which suggested that they were unable to go deeper into the tissues, because they could not enter lymphatic channels as in normal tissue.

In order to find out how long these changes in the joints persist, another series of four rabbits was given three injections of potassium iodide at weekly intervals. These rabbits were killed one, two, three and four months, respectively, after the last injection.

Rabbit 1.—The technic was the same as in the previous series. The swelling disappeared in the joints into which injections were made (right knee and right foreleg) ten days after the last injection. Two-tenths cubic centimeter of mild silver protein solution was injected into the right foreleg and 0.4 cc. into the right knee joint five hours before the animal was killed. The same injections were given in the opposite (normal) elbow and knee joints. When the animal was killed one month later, there was still moderate thickening of the joint capsule. Sections studied immediately with the microscope showed only an occasional lymphatic vessel in the synovial tissues from the joints into which injections were made, while an extensive lymphatic plexus was shown in the synovial tissue from the other side.

Microscopic study showed a moderate proliferation of the synovial membrane, with increased fibrous tissue in the subserous layer on the right side. There was

78. Sigurdson, L. A.: J. Bone & Joint Surg. **12**:603, 1930.

occasional lymphatic infiltration about the blood vessels. There were no definite changes in the bone, cartilage or marrow cavity.

RABBIT 2.—In this rabbit there was swelling of the injected joints, the left knee and foreleg joints, into which injections were made, until one week after the last injection. There was practically no disturbance of function in these joints. There was still moderate capsular thickening about the joints when the animal was killed two months after the last injection. A 1 per cent solution of mild silver protein was injected into both knee and both foreleg joints four hours before the animal was killed. Sections from the synovial membrane studied immediately showed a slightly more abundant plexus in the synovial membrane from the joints on the right side than from that on the left side. There was slightly greater synovial proliferation on the left side, but there were no striking pathologic changes in the joints which had received the injections of potassium iodide.

RABBIT 3.—Swelling was present in the joints into which injections were made, from the first injection until two weeks after the third injection. Definite capsular thickening could be made out about the injected knee joint until the animal was killed three months after the last injection. Four-tenths cubic centimeter of a 1 per cent solution of mild silver protein was injected into both knee joints, and 0.2 cc. into the joints of both forelegs five hours before the animal was killed. There were no apparent macroscopic pathologic changes in any of the joints. Tissue from the synovial membrane studied immediately showed no noteworthy difference in the number and size of the lymphatic vessels from the two sides. The microscopic sections showed no pathologic changes.

RABBIT 4.—Swelling subsided five days after the first injection, but remained practically unchanged in the joints after the second injection until ten days after the last injection. There was appreciable capsular thickening about the knee joint into which an injection was made for about two months. The animal was killed in four months. Mild silver protein was injected into both knee and both foreleg joints four hours before the animal was killed. Tissue studied immediately showed an equally dense lymphatic plexus on both sides. There were no definite pathologic changes in the tissues from the joints that had been given injections of potassium iodide.

These experiments showed that the changes produced in the joints by injections of potassium iodide were in no wise permanent, but gradually subsided in about two months, varying somewhat in different animals. Similar results were obtained by Key,[77] who observed a partial return to normal conditions within twelve days after single injections of india ink or citrated blood into joint cavities. His work suggested that the duration of the inflammation of the synovial tissue might depend somewhat on the severity of the reaction produced, and, also, on the number of injections given. A series of seven animals was given from seven to twelve injections of potassium iodide at weekly intervals to see how long changes in the joints could be made to persist. In the last four animals emulsions of tubercle bacilli were injected into the knee joint for several weeks at weekly intervals before the animals were killed. No infections in the joints into which injections were made were seen, and cultures from the joints were negative at autopsy.

RABBIT 1.—The technic was the same as in previous series. Seven injections of a 20 per cent solution of potassium iodide were made at weekly intervals into the joint cavities of the right knee and foreleg. Swelling subsided in the joints two weeks after the last injection. There was still some palpable thickening of the capsule of the right knee joint when the animal was killed four months after the last injection. A 1 per cent solution of mild silver protein was injected into both knee and both elbow joints five hours before the animal was killed. Both the right knee and the right foreleg showed moderate thickening of the synovial membrane. The cartilage was dull, but otherwise showed no macroscopic pathologic change. Tissue from the synovial membrane studied immediately showed only a few lymphatic vessels on the right side and a fairly numerous plexus on the left side. Microscopic section showed moderate epithelial proliferation of the lining cells. There was a moderate increase in the fibrous tissue in the subserous layers. There was slight lymphocyte infiltration in the synovial membrane, particularly about the blood vessels. The cartilage showed no pannus. There were a few areas of superficial erosion. No changes were seen in the bone or marrow cavity.

RABBIT 2.—In this rabbit nine injections of a 20 per cent solution of potassium iodide were given at weekly intervals. Swelling persisted in the joint for two weeks after the last injection. There was periarticular thickening which remained practically unchanged until the animal was killed six months later. A 1 per cent solution of mild silver protein was injected into both knee and elbow joints four hours before the animal was killed.

Sections of the joint studied immediately showed no lymphatics on the right side and a fairly numerous plexus on the left side. The synovial membrane was moderately thickened. The cartilage showed no change. Fixed sections of tissue showed proliferation of the synovial endothelial cells with a little increase in the fibrous tissue beneath. There was no change in the bone or bone marrow.

RABBIT 3.—This rabbit was given ten injections of potassium iodide at weekly intervals into the right knee and right foreleg joints. The swelling persisted for eighteen days after the last injection. The animal was killed five months after the last injection. Four hours before the animal was killed, a 1 per cent solution of mild silver protein was injected into both knee and both foreleg joints. Synovial membrane studied immediately showed only one short lymphatic vessel on the right side and a moderate number of lymphatic vessels on the left side. Fixed sections showed a moderate endothelial proliferation of the synovial membrane with fibrous proliferation in the subserous layer of the synovial membrane and occasional lymphocytic infiltration about the blood vessels. The cartilage, bone and bone marrow showed no pathologic changes (fig. 8).

RABBIT 4.—This animal was given ten injections of potassium iodide at weekly intervals into the right knee joint and right foreleg joint. Swelling of the joints into which injections were made lasted for three weeks after the last injection. Periarticular thickening could be felt about the right knee until the animal was killed seven months later. During the last month that the animal remained alive, 0.3 cc. of a suspension of human tubercle bacilli of low virulence was injected at weekly intervals for three times into the right knee joint. A 1 per cent solution of mild silver protein was injected into both foreleg joints five hours before the animal was killed. Smears from the right knee showed tubercle bacilli. The synovial membrane was moderately thickened. There were discoloration and slight roughening of the articular cartilage. Sections from the synovial membrane studied immediately with the microscope demonstrated no lymphatics stained by

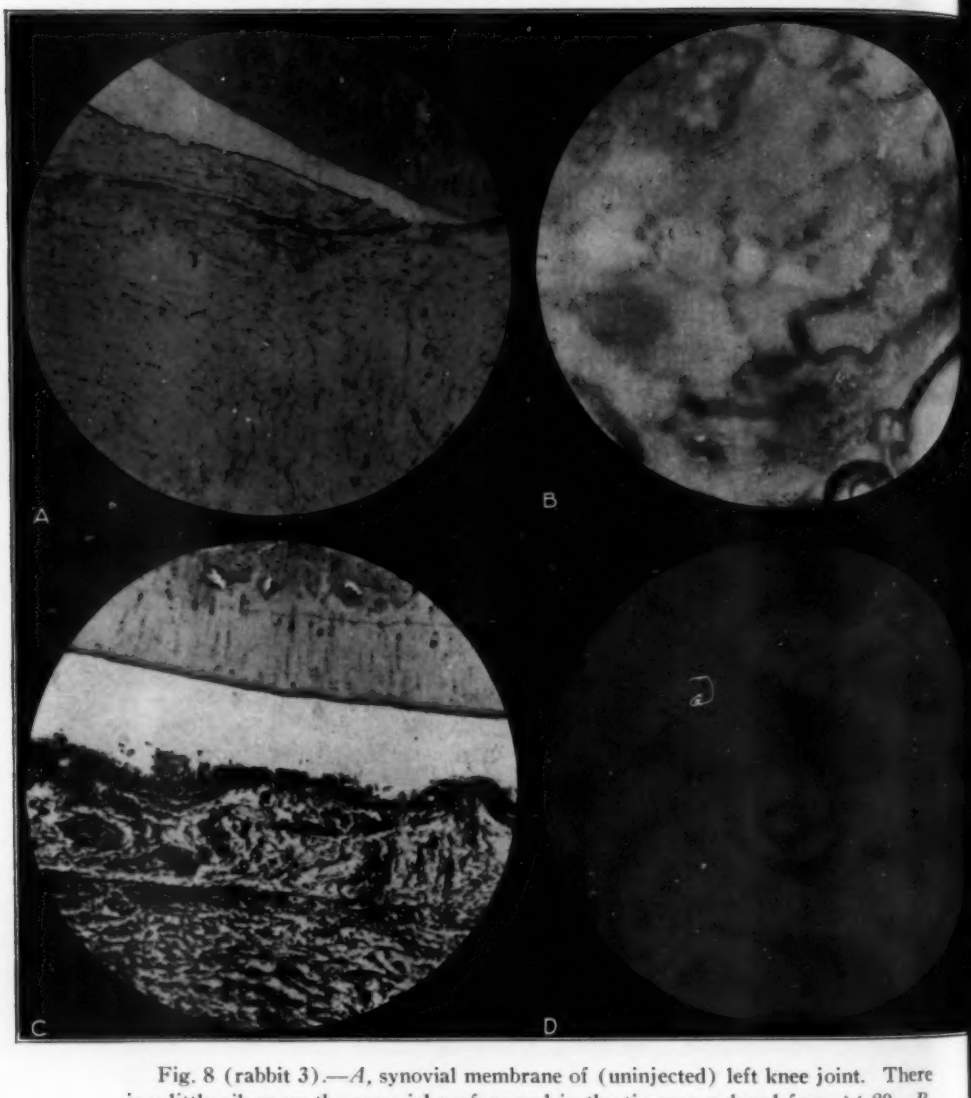

Fig. 8 (rabbit 3).—*A*, synovial membrane of (uninjected) left knee joint. There is a little silver on the synovial surface and in the tissues; reduced from × 80. *B*, same as *A* (fresh tissue). The lymphatics filled with phagocytes, which have taken up silver particles, are fairly numerous; reduced from × 80. *C*, synovial membrane of (injected) right knee joint; reduced from × 100. Note the large amount of silver on the synovial membrane. There are extensive synovial proliferation, vascular congestion and fibrosis. *D*, same as *C*; reduced from × 80. The silver on the synovial surface gives the dark appearance. No lymphatics are visible.

the silver protein on the right side, but showed a fairly numerous plexus of lymphatic vessels on the left side. Microscopic sections showed endothelial proliferation of the synovial membrane, with dilatation of the superficial blood vessels. There was a moderate increase in the subserous fibrous tissue. There was no lymphocytic perivascular infiltration. No evidence of tuberculosis was seen in the synovial membrane, nor were tubercle bacilli seen in sections stained to demonstrate them. The regional lymph nodes showed no evidence of tuberculous infection.

Rabbit 5.—This rabbit was given ten injections of potassium iodide at weekly intervals into the right knee and foreleg joints. Swelling of the knee joints lasted for almost four weeks after the last injection. There was periarticular capsular thickening, which persisted until the animal was killed eight months later. In spite of this, there was no appreciable disturbance in function after the swelling of the knee joints had subsided. A suspension of human tubercle bacilli of low virulence was injected at weekly intervals for three times into the right knee joint, which had previously received injections of potassium iodide. The animal was killed one week after the last injection of tubercle bacilli. A 1 per cent solution of mild silver protein was injected into both elbow joints four hours before the animal was killed. There was definite and rather marked thickening of the synovial membrane in the right knee and elbow joints. The cartilage was dull in appearance and was slightly roughened. Smears from the joint cavity showed tubercle bacilli. The regional lymph nodes were not enlarged. Sections from the synovial membrane studied immediately showed no lymphatic vessels on the right side and a fairly abundant plexus of lymphatics in the synovial membrane on the left side. Fixed sections from the right knee joint showed marked thickening of the joint capsule with increased villous formation. There was extensive proliferation of the synovial endothelium. There was occasional lymphocytic infiltration about the blood vessels and in the subserous tissue. There were moderate edema and vascular congestion of the synovial membrane. Slight fibrosis was noted in the subserous synovial tissue. There were many more lymph vessels containing phagocytes, with silver particles in the tissue from the left side, which showed no pathologic changes. The cartilage of the right knee showed slight superficial erosion. The bone marrow cavity showed no abnormality. The regional lymph nodes showed no tubercle bacilli and no evidence of tuberculous infection.

Rabbit 6.—This rabbit was given twelve injections of potassium iodide at weekly intervals into the right knee and foreleg joints. Swelling of the joints lasted for four weeks after the last injection. Palpable capsular thickening could be felt about the joints into which injections were made until the animal was killed ten months after the last injection. One month before the animal was killed and at weekly intervals thereafter for two subsequent times, a suspension of avirulent human tubercle bacilli was injected into the right knee joint. Four hours before the animal was killed, a solution of mild silver protein was injected into both elbow joints. When the joints were opened, a marked thickening of the joint capsule with villous formation was observed on the right side. There was slight erosion of the cartilage, which had a dull brownish color. Smears from the joint cavity of the right knee showed a few tubercle bacilli. The regional lymph nodes were not enlarged. Tissue from the synovial membrane of the right foreleg showed no lymphatics, while an extensive lymphatic plexus was shown in the synovial tissue from the left foreleg joint. Fixed sections showed no lymphatics in the tissue from the joint which had received injections, while an extensive

lymphatic plexus was shown in the synovial tissue from the joint of the other foreleg. Fixed sections showed the same changes on the right as described in rabbit 5. The lymph nodes draining the right knee showed no tuberculous infection in microscopic sections (fig. 9).

RABBIT 7.—Twelve injections of potasium iodide were made at weekly intervals into the joint cavities of the right knee and foreleg. Swelling of the joints persisted almost four weeks after the last injection. There was thickening of the joint capsule, particularly in the right knee joint, which lasted until the animal was killed nine months after the last injection. A suspension of avirulent human tubercle bacilli was injected into the right knee joint at weekly intervals for three times. One week after the last injection, the animal was killed. A 1 per cent solution of mild silver protein was injected into the joints of both forelegs four hours before the animal was killed. Smears from the synovial fluid of the right knee showed tubercle bacilli. The synovial membrane was markedly thickened on the right side. There was slight erosion of the articular cartilage, but no pannus formation. Sections from the synovial membrane of the elbows showed no lymphatics on the right side, and a fairly abundant plexus of lymphatics on the left side. Microscopic sections showed marked endothelial proliferation of the synovial membrane, with an increase in fibrous tissue in the subserous layer. Occasional lymphocytic infiltration about the blood vessels was seen. The cartilage showed slight superficial necrosis, but no change was seen in the bone or bone marrow. The lymph nodes draining the right knee and the synovial tissue of the right knee, as well, showed no evidence of tuberculous infection.

These experiments showed that the changes produced by injections of potassium iodide into joint cavities could be made relatively lasting if the injections were continued for a long enough period. Young[79] reported that while a single intrapleural injection of an electrolyte (strontium chloride) produced extensive epithelial proliferation in the pleura of rabbits, a second injection within eight days did not increase the amount of epithelial proliferation. A new reaction of epithelial proliferation by the pleura was not observed until the first reaction had subsided in about twenty days. This was not found to be the case in the reaction of the joint cavities of rabbits. Repeated injections of potassium iodide at weekly intervals produced a gradually increasing epithelial proliferation which was relatively commensurate with the number of injections given. The early experiments with single injections of potassium iodide showed that an almost complete restitutio ad integrum of the synovial membrane had occurred within one week. Whether a reaction on the part of the synovial membrane would have occurred with injection at shorter intervals was not determined.

The pathologic lesions that were produced in these animals were an arthritis in the sense of being an inflammation of a joint, but they did not fill the picture of the changes in the human joints as observed in atrophic arthritis (Nichols and Richardson[80]). The histologic

79. Young, J. S.: J. Path. & Bact. **34**:357, 1931.

80. Nichols, E. H., and Richardson, F. L.: J. Exper. Med. **16**:149, 1909.

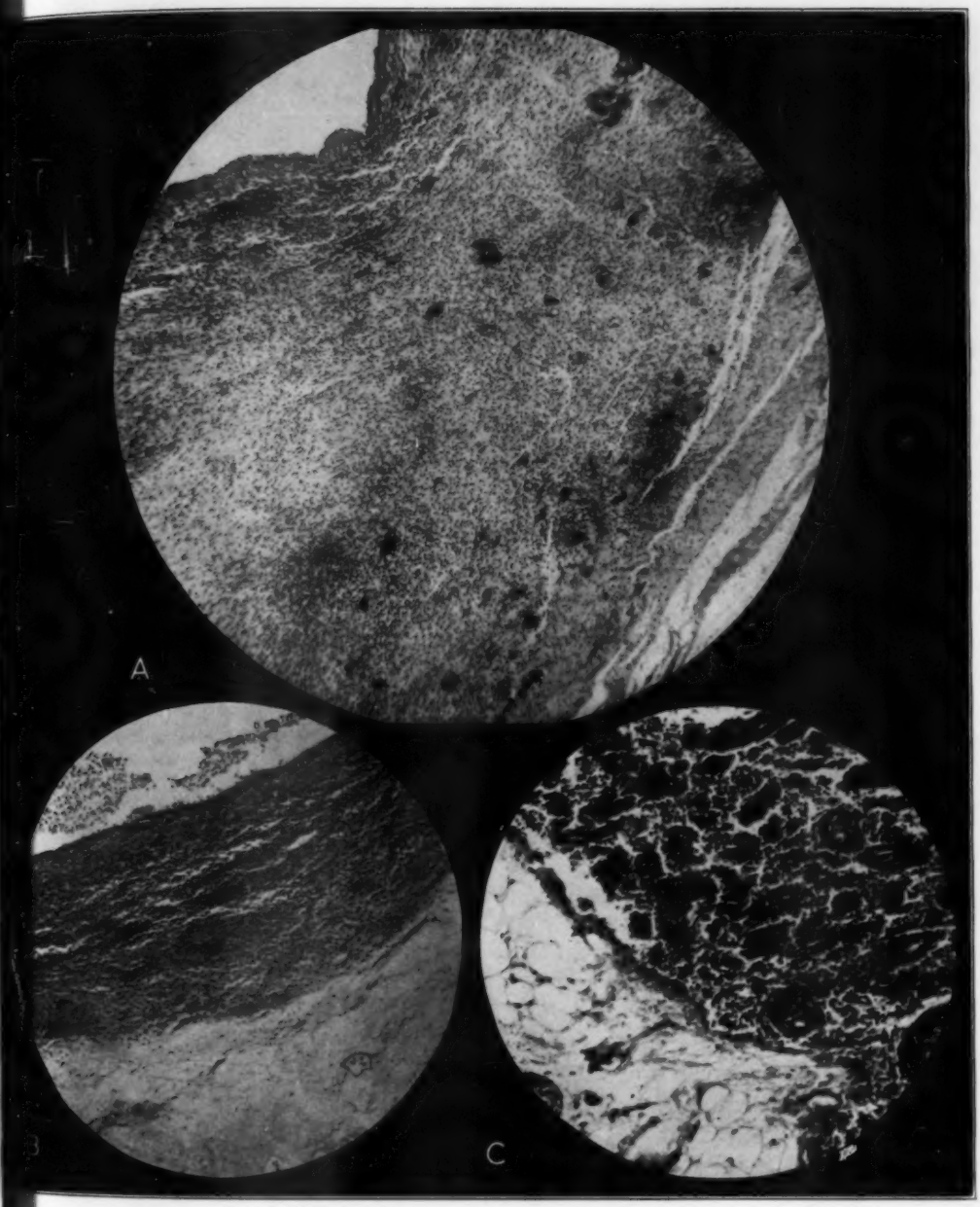

Fig. 9 (rabbit 6).—*A*, synovial membrane, right knee. There is endothelial proliferation, with marked thickening of the entire synovial membrane, fibrosis and occasional lymphocytic infiltration; reduced from × 90. *B*, same as *A*; reduced from × 70. Note the exudate on the synovial membrane, with some silver particles. There is no tuberculous infection. *C*, right external iliac lymph node; reduced from × 125. There is no evidence of a tuberculous infection.

changes in the synovial membrane were somewhat similar but milder than those seen in atrophic arthritis. In no case was any pathologic change observed in the bone or bone marrow. The erosion of the cartilage and the destruction of cartilage cells were slight and superficial. There was never any pannus formation. In the cases in which repeated injections of potassium iodide alone were given, no change could be seen in the regional lymph nodes. This was to be expected, since a salt in molecular solution, so far as is known, is absorbed only by the blood vessels. It is conceivable, however, that changes in the regional lymph nodes might have occurred in the absorption of the exudate and cells thrown out against the inflammatory agent that was injected. Von Meyerding [81] found that in repeated infections the regional lymph nodes often showed a heightened reaction to subsequent infections, with increased dilatation of the blood vessels, swelling and proliferation of the sinus epithelium, but that otherwise there was no difference between single and repeated infections. In these cases no such reaction on the part of the lymph nodes could be made out.

No evidence of absorption of tubercle bacilli after repeated injections of tubercle bacilli into the knee joint was seen in the regional lymph nodes draining the joint cavities that had received many injections of potassium iodide. Apparently the pathologic changes in the lymphatics produced by the potassium iodide prevented the taking up of the bacilli by the lymphatics. Boquet, Valtis and Saenz,[82] in experiments on tuberculous infection, showed that the tubercle bacilli, after injection into normal tissues, quickly entered the lymphatics; the tubercle bacilli then passed to the blood stream and the viscera. In anything short of massive doses, the bacteria were found in the regional lymph nodes within several hours. Powlowsky,[83] in 1909, found that the dissemination of bacteria from joint cavities was markedly decreased when an inflammation was present in the joint cavity. He did not study the lymphatics, however. Opie [84] observed that acute inflammation in the peritoneal cavity of dogs retarded the absorption of bacteria injected into the peritoneal cavity and after twenty-four hours wholly prevented the absorption of such bacteria.

Both Job [53] and Meyer [41] observed, in older experimental animals, that the lymphatics appeared to be less numerous and that they could be demonstrated less readily; they also found an apparent decrease in size in the lymph nodes with increasing age. Because of this my work was done entirely with young adult animals. Job [53] suggested a natural involution of the lymphatic system with age similar to that observed in

81. von Meyerding, H.: Schweiz. med. Wchnschr. **59**:593, 1929.
82. Boquet, A.; Valtis, J., and Saenz, A.: Ann. Inst. Pasteur **46**:373, 1931.
83. Powlowsky, A. D.: Ztschr. f. Hyg. u. Infektionskr. **62**:433, 1909.
84. Opie, E. L.: J. Immunol. **17**:329, 1929.

the circulatory system for the blood. W. J. Mayo [72] stated that this apparent involution of the lymphatic tissue in elderly persons was a possible reason for the decreased virulence of infection and malignant disease in such persons.

Because the experimental work for this article had been done wholly on rabbits and because the lymphatic changes had been produced by chemicals, an attempt at corroboration of the findings was sought in human joint tissues. Healthy synovial membrane was obtained in twelve cases of infantile paralysis, in which arthrodeses were performed on joints. Grant [85] has recently shown that a fairly extensive synovial membrane with intra-articular folds was present even in the carpal and tarsal joints. In these cases an adequate amount of synovial tissue was always found attached to the cartilage removed at operation. The pathologic tissue studied was obtained in twelve cases: from operations for the correction of deformities in atrophic arthritis in eleven cases and from a chronically inflamed bursa in one case. Since no injections into the joints or bursa could be made, synovial tissue was studied immediately with hydrogen dioxide as previously described. Sections were also studied microscopically in fixed preparations. A brief outline of the cases and findings is given.

"NORMAL" SYNOVIAL TISSUE

CASE 1.—A. R., 7½ years old, had infantile paralysis of four years' duration. Tissue was obtained from the astragaloscaphoid joint. The synovial tissue treated with hydrogen dioxide showed many small lymphatics. Microscopic sections showed no pathologic changes in the synovial membrane.

CASE 2.—G. M., 9½ years old, had had infantile paralysis three years before. Tissue was obtained from the subastragalar joint. Hydrogen dioxide demonstrated a fair number of small lymphatics. The synovial membrane showed no abnormality on microscopic examination.

CASE 3.—D. G., aged 6, had infantile paralysis of four years' duration. Tissue was obtained from the subastragalar joint. The application of hydrogen dioxide to thin sheets of tissue showed many lymphatic vessels in the synovial membrane. The synovial membrane showed no pathologic lesion on microscopic study.

CASE 4.—L. W., 8 years of age, had had infantile paralysis four years before. Tissue was obtained from the subastragalar joint. Hydrogen dioxide showed a dense plexus of lymphatic vessels in the fresh synovial tissue. The synovial membrane showed no abnormality on microscopic examination (fig. 10).

CASE 5.—F. M., aged 6, had infantile paralysis of five and three-fourths years' duration. Tissue was obtained from the subastragalar joint. Many lymphatics were visible in the synovial membrane after the application of hydrogen dioxide. Microscopically, the synovial membrane showed no pathologic changes.

CASE 6.—A. R., aged 4, had infantile paralysis of two years' duration. Tissue was obtained from the subastragalar joint. Hydrogen dioxide, applied to

85. Grant, J. C. B.: Brit. J. Surg. **18**:636, 1931.

the synovial membrane, showed many fine lymphatic vessels. The synovial membrane showed no pathologic changes on microscopic examination.

CASE 7.—T. A., aged 4, had had infantile paralysis one and one-half years before. Tissue was obtained from the subastragalar joint. Many lymphatic

Fig. 10.—*A*, normal human synovial tissue; reduced from × 80. *B*, fresh human synovial tissue treated with hydrogen dioxide; reduced from × 80. Many of the lymphatics have been cut across in removing the tissue. *C*, same as *B*, showing large lymphatic vessel with branches; reduced from × 240.

vessels were seen in the synovial membrane after the application of hydrogen dioxide. The synovial membrane showed no pathologic lesion.

CASE 8.—C. F., aged 9, had had infantile paralysis five years before. The tissue was obtained from the calcaneocuboid joint. Hydrogen dioxide showed many lymphatics in the synovial membrane. The cartilage and synovial membrane showed no pathologic lesions.

CASE 10.—G. G., aged 10, had infantile paralysis of four years' duration. Tissue was obtained from the astragaloscaphoid joint. Many lymphatic vessels were seen in the synovial membrane after the application of hydrogen dioxide. Microscopically, the synovial membrane showed no pathologic lesions.

CASE 12.—E. C., 9 years of age, had infantile paralysis of three years' duration. Tissue was obtained from the subastragalar joint. Hydrogen dioxide demonstrated many lymphatic vessels in the synovial membrane. Microscopically, the joint tissues showed no pathologic lesion.

DISEASED SYNOVIAL TISSUE

CASE 1.—D. S., aged 54, had chronic bursitis of the right shoulder of nine months' duration. Operation consisted in incision and curettage of an infected bursa. The tissue showed a markedly thickened bursal wall with occasional deposition of calcium, old hemorrhage in the tissues and extensive lymphocytic and leukocytic infiltration. Fresh tissue treated with hydrogen dioxide showed no lymphatic vessels.

CASE 2.—E. J., aged 38, had generalized atrophic arthritis of seven years' duration. Synovectomy was performed on the right knee. The markedly thickened synovial membrane showed only one small lymphatic vessel after the application of hydrogen dioxide. Microscopic sections showed extensive venous congestion and thickening of all the layers of the synovial membrane, with occasional lymphocytic and fatty infiltration (fig. 11).

CASE 3.—M. M., aged 35, had atrophic arthritis of six years' duration. Arthroplasty was performed on the left knee. Both hydrogen dioxide and the injection of india ink into the synovial tissues demonstrated no lymphatic vessels. The synovial membrane was markedly thickened, with extensive villous formation. Microscopic sections showed a thickening of the epithelial layer of the synovial membrane, an increase in fibrous tissue in the subserous layer and occasional lymphocytes about the blood vessels.

CASE 4.—E. J. (case 2), underwent synovectomy of the left knee six months after the first operation. The markedly thickened synovial membrane showed no lymphatic vessels after the application of hydrogen dioxide. Microscopic sections showed a pathologic picture similar to that described in the tissue from the right knee.

CASE 5.—G. P., aged 16, had intermittent hydrops of the right knee of eight years' duration. Synovectomy was performed. No lymphatics were seen in the synovial membrane after the injection of india ink directly into the synovial tissues. Two short, dilated lymphatics were seen after the application of hydrogen dioxide. Microscopically, the synovial membrane showed marked venous congestion, slight thickening of all the layers and occasional aggregations of lymphocytes about the dilated blood vessels.

CASE 6.—L. M., aged 28, had atrophic arthritis of sixteen years' duration. Operation consisted in resection of the first left metatarsophalangeal joint. No lymphatics were seen in the synovial membrane after the injection of india ink directly into the tissues or by the use of hydrogen dioxide. Microscopically, the

Fig. 11 (case 2).—*A*, synovial membrane, showing thickened synovial membrane with endothelial proliferation, marked vascular congestion and fibrous increase in subendothelial tissue; × 120. *B*, same as *A*, treated with hydrogen dioxide. One short, thick lymphatic vessel is seen; × 90.

synovial tissue showed nothing but fibrous tissue. No vestiges of the synovial endothelium remained.

CASE 7.—E. F., aged 28, had atrophic arthritis of five years' duration. Arthroplasty of the left hip was performed. Synovial tissue treated immediately with hydrogen dioxide showed no lymphatics. Microscopic sections showed thickening of the synovial membrane, with endothelial proliferation, an increase of fibrous tissue in the synovial membrane, marked congestion, slight pannus and erosion of the cartilage.

CASE 8.—J. M., aged 45, had villous arthritis of the left knee of ten years' duration. Synovectomy was performed on the left knee. Fresh synovial tissue treated with hydrogen dioxide showed one short lymphatic vessel. Microscopic sections showed a markedly thickened synovial membrane, with vascular congestion, endothelial proliferation and lymphocytic infiltration about the blood vessels.

CASE 9.—E. S., aged 7, had atrophic arthritis of five years' duration. Synovectomy was performed on the left knee. Tissues from the synovial membrane treated with hydrogen dioxide showed no lymphatic vessels. Microscopic sections showed a very thick, edematous synovial membrane, with dilatation of all the blood vessels and occasional lymphocytes about the blood vessels.

CASE 10.—C. B., aged 50, had atrophic arthritis of twenty-four years' duration. Arthroplasty was performed on the left elbow. Fresh synovial tissue showed no lymphatic vessels after the application of hydrogen dioxide. Microscopic section showed a thickened synovial membrane, with dense fibrous tissue throughout. There was no vascular congestion and no endothelial proliferation.

CASE 11.—M. B., aged 35, had atrophic arthritis of twelve years' duration. Synovectomy was performed on the right knee. Synovial tissue treated immediately with hydrogen dioxide showed two short lymphatic vessels. Microscopic sections showed a villus-like projection of the synovial membrane, with vascular congestion and fatty infiltration.

CASE 12.—C. S., aged 37, had atrophic arthritis of nine years' duration. Synovectomy was performed on the left knee. Hydrogen dioxide applied to fresh synovial tissue showed no lymphatics. Microscopic sections showed a thickened, edematous synovial membrane, with vascular engorgement and occasional accumulation of lymphocytes about the blood vessels. There was a moderate increase in fibrous tissue in the synovial membrane.

The synovial tissues obtained from human joints confirmed the findings in regard to the lymphatics as seen in the joints of rabbits. In the synovial tissues obtained from the joints of patients suffering from infantile paralysis, in whom there was no disease of the joint clinically or on microscopic examination of the tissues from the joint, the lymphatics were readily demonstrated as numerous small inflated vessels by the use of hydrogen dioxide. In the cases of atrophic arthritis or chronic bursitis only an occasional lymphatic vessel, and in most of the cases no lymphatic vessels, could be seen. So far as could be determined, no normally functioning lymphatics were present. Lymphatic vessels were demonstrated with extreme difficulty in such diseased tissue. Whether they had become collapsed by the outpouring of inflam-

matory exudate or whether they were thrombosed could not be definitely determined either by injections or in sections cut to show them in cross-section.

It is not known exactly what rôle a disturbance in function in the lymphatic vessels plays in arthritis, but there is much suggestive evidence that it is an important factor in producing decreased absorption and in preventing the subsidence of the swelling in the synovial membrane. Drinker [86] has suggested that in injury, blood plasma fills the intercellular spaces. This in turn encourages fibrous proliferation, if the plasma cannot readily be removed by the lymphatics. In this way the subsidence of the inflammatory reaction in tissue may be prevented, and chronic fibrous tissue may remain indefinitely if the early inflammatory exudate and cellular débris cannot be removed by the phagocytes and lymphatics. This is more than an interesting hypothesis. Since 1911, when Kondoleon [87] devised an operation for the treatment of elephantiasis, supposing that it was due to lymphatic obstruction, investigators have sought the cause of persistent fibrosis and edema in tissues. The recent studies of Reichert,[88] as well as the earlier investigations of Clark and Clark [89] and Matas,[90] have shown that chronic inflammation and lymph stasis combine to produce the pathologic and clinical picture of elephantiasis in tissues. That its persistence is due to lack of lymphatic absorption is strongly suggested by the work of Menkin,[91] who found that india ink or graphite did not reach the regional lymph nodes when injected into an area of inflammation. This he believed to be due to thrombosis of the lymphatics.

CONCLUSIONS

1. Lymphatics are present as abundant small vessels in the tissues lining joint cavities. They are most numerous just beneath the endothelial cell layer of the synovial membrane.

2. The lymphatic drainage of the joints in the lower extremity is through the so-called deep lymphatics to the popliteal, deep femoral and iliac lymph nodes.

3. Inflammation in the synovial tissues results in a decreased ability on the part of the lymphatics to absorb material larger than of molecular

86. Drinker, C.: Lecture before Harvard Medical Society, Nov. 12, 1929.

87. Kondoleon, E.: Zentralbl. f. Chir. **39**:1022, 1912.

88. Reichert, F. L.: The Recognition of Elephantiasis and of Elephantoid Conditions by Soft Tissue Roentgenograms, Arch. Surg. **20**:543 (April) 1930.

89. Clark, E. W., and Clark, E. R.: Anat. Rec. **21**:127, 1921.

90. Matas, R.: Am. J. Trop. Dis. **1**:60, 1913.

91. Menkin, V.: J. Exper. Med. **53**:647, 1931.

size. An apparent obliteration of the lymphatic vessels occurs when the inflammatory process is sufficiently severe or long continued.

4. With the subsidence of the inflammatory reaction, the lymphatics are again seen in their usual size and distribution, and absorption of particulate substances is again observed by the lymphatic vessels.

5. Persistent inflammation in synovial tissues is dependent to a certain extent on the nonfunction of the lymphatic vessels.

WOUND OF THE SUPERIOR VENA CAVA TREATED BY SUTURE

REPORT OF A CASE

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Wounds of the great vessels within the mediastinum are rare and are usually rapidly fatal. When such a vessel is injured outside the pericardium, the signs and symptoms are those of massive intrathoracic hemorrhage; whereas if the intrapericardial portion is injured, cardiac tamponade is apt to result. No case of repair of such a wound can be found in the literature. Because of this fact and because of the importance of recognizing the possibility of such a wound so as to make an incision which will give adequate exposure, the following case is reported.

REPORT OF CASE

History.—S. B., a colored man, aged 34, was admitted to the Saint Philip Hospital, on Feb. 1, 1932, complaining of a stab wound of the right side of the chest and incised wounds of the left wall of the chest and the left hand. He had received the wounds about thirty minutes before admission to the hospital.

Examination.—On examination the patient was apparently in a state of profound shock. There had been little external loss of blood, and there were no physical signs of massive internal hemorrhage. The stab wound in the right side of the chest had penetrated the third costal cartilage 1 cm. to the right of the sternum. The wound in the left wall of the chest was at the level of the eighth rib in the posterior axillary line and obviously had not penetrated the pleural cavity. The wound on the left hand was of little importance. There was flatness at the base of the right lung posteriorly, indicating a moderate collection of fluid in the right pleural cavity, but there was no evidence of pneumothorax. Auscultation over the pericardial area showed the heart sounds to be distant and muffled, but percussion did not reveal an appreciable enlargement of the area of pericardial dulness. Because of the distant muffled heart sounds and the extreme circulatory failure, which was out of proportion to the loss of blood, it was thought that the patient had a wound of the heart; hence immediate operation was advised. Because of the fact that the wound was located in the upper portion of the chest, it was thought that it had probably entered the right auricle; the incision was made on the right side.

Operation.—With the patient under local anesthesia (a 0.5 per cent solution of procaine hydrochloride), a curved incision was made over the second costal

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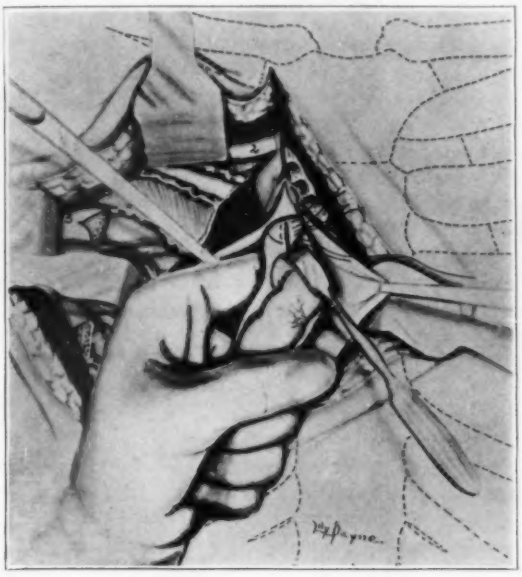

Fig. 1.—Drawing showing the excellent exposure of the right auricle and the intrapericardial portion of the superior vena cava and the method used to control hemorrhage.

Fig. 2.—Photograph taken twenty-two days after operation, showing the location and appearance of the incision.

cartilage near the sternum and carried downward and outward to the upper border of the fifth rib and out along the rib to the anterior axillary line. The stab wound was excised. The pectoral muscles were divided and retracted upward and outward, and the second, third and fourth cartilages exposed. The third and fourth cartilages were excised and the second cartilage divided and retracted upward. The internal mammary vessels were ligated and divided. The right border of the sternum was rongeured away between the second and fifth cartilages. The right pleura was found to extend unusually far to the left, so the pleura was opened; about 500 cc. of blood was found. The pericardium was tense, and obviously contained a large amount of blood. A wound about 1 cm. in length was found in the right side of the upper portion of the pericardial sac. This wound was enlarged and the pericardial cavity widely exposed, whereupon dark blood gushed from the upper portion of the sac. Further examination revealed a wound 1 cm. in length in the anterior wall of the superior vena cava immediately above the right auricle and partially covered by the right auricular appendage. The hemorrhage was partially controlled by passing the index finger of the left hand posterior to the vena cava, and the wound was closed with three interrupted mattress sutures of silk. The pericardium was not closed. The pleura was approximated with interrupted sutures of chromic catgut, the muscles with chromic catgut and the skin with silk. During the closure of the wound in the vena cava, the patient's heart began to fibrillate and continued to do so for about thirty minutes. It was thought that this was probably due to traction in the region of the sino-auricular node.

Postoperative Course.—At the time of the patient's return to the ward the systolic blood pressure was 90 mm. of mercury and the pulse was of good volume but still irregular. On the following day, the systolic blood pressure remained around 100 to 110 mm. of mercury; the temperature remained around 100 F., and the pulse rate ranged between 120 and 135. The second day after operation the temperature rose to 104 F. and the pulse rate to 140; both remained elevated for four days. At this time roentgen examination showed areas of increased density in the lower lobe of the right lung and in the left costophrenic angle, which were interpreted as areas of atelectasis. A moderate collection of fluid accumulated in the right pleural cavity, and there was some displacement of the mediastinum to the left. The leukocyte count made on the second day after operation, at the time of the marked elevation of temperature, was 14,700, the hemoglobin, 45 per cent and the polymorphonuclears, 80 per cent; at this time the blood pressure was 150 mm. of mercury systolic and 120 diastolic. The blood pressure remained high for about four days and then gradually fell to 120 mm. of mercury systolic and 85 mm. diastolic. Unfortunately, electrocardiographic tracings were not made until the heart had regained a normal rhythm; several which were made during the convalescence were normal.

At the time of the patient's discharge from the hospital, on March 3, thirty-two days after operation, the general condition was favorable; the pulse was regular and of good volume; the wound had completely healed, and examination of the heart showed no abnormal findings in regard to size or to function.

CLINICAL CONSIDERATION OF GASTRIC ULCER AND CARCINOMA

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It is a debated question among pathologists whether a high or a relatively low percentage of gastric ulcers undergo carcinomatous transformation. McCarty [1] said that 68 per cent of resected ulcers are associated with carcinoma; Wilensky and Thalhimer [2] found that 1 or 2 per cent of ulcers develop into carcinoma. In this presentation I shall deal with the clinical aspects of the problem and not enter into the histopathologic debate. One must decide whether medical treatment is ever justifiable or whether the patient should be subjected at once to subtotal gastrectomy. In view of the difference of opinion among pathologists, one is justified in basing a clinical descision on the number of ulcers, diagnosed clinically and roentgenologically, that subsequently manifest carcinomatous changes. One must, of course, make a differential diagnosis between ulcer and carcinoma, and this is frequently difficult when the latter is in an early stage. Friedenwald and Baetzer [3] in 1913 called attention to the use of roentgen examination in the determination of the degree of healing of an ulcer, which cannot be as certainly determined in any other way. In the borderline cases it may be necessary to resort to a Sippy regimen before the roentgenologist can commit himself to a decision between ulcer and early carcinoma. In early carcinoma medical treatment rarely abolishes pain; the lesions are not diminished on subsequent roentgen examination and may actually have increased in size. It is not fair always to expect a roentgenologist to commit himself to a positive statement on one examination of the gastro-intestinal tract any more than to expect a clinician to make a positive diagnosis from a physical examination without the aid of laboratory data; but if a competent roentgenologist has the opportunity to base his diagnosis of ulcer on a second examination after a brief Sippy regimen, subsequent diagnosis of carci-

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1. McCarty, Wm. C.: Surg., Gynec. & Obst. **10**:449 (May) 1910.
2. Wilensky, Abraham O., and Thalhimer, William: Ann. Surg. **67**:215 (Feb.) 1918.
3. Friedenwald, J., and Baetzer, F. H.: Tr. A. Am. Physicians **28**:157, 1913.

noma is seldom made. Buckstein [4] stated that he had rarely seen an ulcer diagnosed by himself which at a subsequent date he had been able to demonstrate to be a carcinoma. It is admitted that a roentgenologist with limited experience in gastro-intestinal work may have considerable difficulty in differentiating the two lesions. Balfour [5] in 1930 reported 100 cases of gastric ulcer in which gastro-enterostomy was done without excision of the ulcer. These patients were followed for a ten year period, and only 6 of them died from carcinoma during that time; approximately 80 per cent were symptomatically well. Balfour admitted that the lesions were so large and fixed that any procedure other than gastro-enterostomy would have carried a high mortality, and it was questionable at the time of operation whether benefit could be derived from gastro-enterostomy without excision of the ulcer. The clinical observations of Balfour are in keeping with Ewing's [6] conclusion, from pathologic observations, that about 5 per cent of gastric ulcers develop into carcinoma.

My associates and I observed 460 peptic ulcers in the gastro-enterologic clinic of the Fourth Medical and Surgical Divisions of Bellevue Hospital from January, 1928, to January, 1932. There were 332 nonoperative cases and 128 operative cases. In the nonoperative cases there were 280 duodenal, 31 gastric, 14 pyloric and 7 double (a lesion in both the stomach and duodenum) ulcers. It is interesting to note that we have not seen a case clinically in which carcinoma has developed from an ulcer. The insidiousness of the onset of carcinoma of the stomach was well illustrated in the 15 cases that we observed during this time; the lesion was far advanced in all when the patients were admitted. Alvarez,[7] in 1931, reported 41 cases of carcinoma of the stomach in physicians and called attention to the fact that gastric ulcer is a frequent forerunner of cancer; but in 20 of his cases the shortness of the history testified again to the insidiousness of the onset. If the neoplasm were accompanied by the pain characteristic of gastric ulcer, these physicians would have been astute enough to recognize the symptoms of ulcer and would have received either medical or surgical treatment.

There is an important question that must be answered if carcinoma bears any relation to ulcer: Why does one not see carcinoma of the duodenum arising from duodenal ulcer? It is known that primary

4. Buckstein, Jacob: Personal communication.

5. Balfour, Donald C.: Results of Gastro-Enterostomy for Ulcers of the Duodenum and Stomach, Ann. Surg. **92**:558 (Oct.) 1930.

6. Ewing, James: Ann. Surg. **67**:715 (June) 1918.

7. Alvarez, Walter C.: How Early Do Physicians Diagnose Cancer of the Stomach in Themselves? A Study of the Histories of Forty-One Cases, J. A. M. A. **97**:77 (July 11) 1931.

carcinoma of the duodenum frequently occurs, and carcinoma in this portion of the small intestine is more commonly encountered than in the remainder of the entire small intestine. Duodenal ulcer in our series occurred in a ratio of about 8:1 in comparison with gastric lesions. With the frequency of duodenal lesions and the relative frequency of primary carcinoma of the duodenum it would seem that the ulcer-carcinoma sequence would occasionally be encountered, but a careful review of the literature [8] on this subject failed to reveal a definitely proved case. The transformation of the epithelial cells at the pylorus is gradual, and there is no abrupt change from the pylorus to the duodenum; this is an added reason why carcinoma should develop in duodenal ulcers.

The following cases will illustrate the misunderstanding that frequently arises in evaluating the life cycle of an ulcer unless one has a complete history and clinical record with the roentgenologic findings of the case.

REPORT OF CASES

CASE 1.—A man, aged 46, was admitted to the hospital on Oct. 24, 1927; he had been complaining for six months of pain in the stomach before and after meals, which was not relieved by food but was alleviated by sodium bicarbonate. During the past three months he had lost from 15 to 20 pounds (7 to 9 Kg.). Roentgenologic examination of the gastro-intestinal tract on October 27 revealed carcinoma of the pylorus, with one third of the motor meal retained at the end of six hours. Operation on October 29 revealed an ulcer of the first portion of the duodenum, ½ inch (1.27 cm.) distal to the pyloric vein; posterior gastro-enterostomy was done. The patient was followed in the gastro-enterologic clinic; he was symptom-free until April, 1930, when the abdomen became distended and he began to vomit, with loss of weight. Early in July he became jaundiced, and was readmitted on July 25. Roentgenologic examination on June 25 revealed carcinoma of the pylorus. At operation, on July 31, a carcinoma of the pylorus was found with general abdominal metastases and biliary obstruction; cholecysto-jejunostomy was done, but the patient died on August 1.

From the history, results of roentgen examination and subsequent course there is nothing to indicate a duodenal ulcer except the operator's findings.

CASE 2.—A man, aged 61, was admitted to the hospital on June 17, 1930. The chief complaint was pain in the epigastrium for two months. There had been no serious illness or surgical operations. The patient smoked from twenty to thirty cigarets daily and drank occasionally, usually whisky. He stated that he had been well until two months before, when he began to suffer from pain in the epigastrium and eructations. The pain began in the right upper quadrant of the abdomen near the midline and radiated to the back on both the right and the left side of the spine, extending as high as the scapula. It came on about four hours after breakfast and about the same time after lunch and also awakened him about 2 a. m. The pain was relieved by alkalis and somewhat by pressure over the epigastrium. He had never vomited, but had always been constipated; during the past two

8. Hinton, J. William: Does Carcinoma of the Duodenum Ever Arise from Duodenal Ulcers? Am. J. M. Sc. **181**:843 (June) 1931.

months he had noticed tarry stools. His appetite was good, but he was afraid to eat as it caused pain. During his illness he had lost from 15 to 18 pounds (7 to 8 Kg.).

Physical examination gave negative results except for abdominal findings. No definite mass was palpated, but there were localized tenderness in the mid-epigastrium and slight costovertebral tenderness. The clinical impression was that the condition was carcinoma of the stomach. On June 18 urinalysis gave negative results; the white blood count was 10,000, with 55 per cent neutrophils; the red blood count was 3,500,000; there was 55 per cent hemoglobin; the nonprotein nitrogen was 35 mg. per hundred cubic centimeters, creatinine was 2.4 mg., and sugar 90 mg; the Wassermann test was negative. After four gastro-intestinal roentgen examinations, a diagnosis of ulcer of the first portion of the duodenum was made with no evidence of neoplasm of the stomach and with no six hour residue. On June 24, a barium enema showed no organic lesions of the colon. On June 28, the gallbladder was not clearly defined by cholecystography. On June 26 this note was made by the house physician: "Patient is suffering considerable pain at night, which causes him to awaken about 2 a. m., pain being in midepigastrium and radiating to the back. The patient has complained of pain every night since admission. Impression: penetrating ulcer of the duodenum." Surgical consultation was held on July 3. The patient had been vomiting for twenty-four hours and was emaciated, complaining of severe abdominal pain which radiated to his back. Examination did not reveal any abdominal masses, but there were localized tenderness in the midepigastrium and costovertebral tenderness. The diagnosis was penetrating ulcer of the posterior wall of the duodenum, associated with chronic pancreatitis.

The patient was given a 3 per cent dextrose hypodermoclysis daily and a transfusion the day before operation. He was operated on on July 11 by Dr. W. T. Doran, under spinal anesthesia. A mass was found involving the pylorus and was deemed to be malignant, but, as it was firmly fixed, glands were not obtainable for biopsy; no nodules were felt in the liver. Owing to the patient's serious condition, posterior gastro-enterostomy was then done without clamps. The patient declined in spite of supportive measures and died on July 20, 1930.

The observations at autopsy (reported by Dr. D. Symmers) were as follows: "In the first portion of the duodenum there is a hard, nodular, faintly cream-colored mass which is centrally ulcerated and which measures 6.5 cm. in diameter. It projects into the lumen of this portion of the intestine in somewhat mushroom fashion, and appears to be directly continuous with the outer 2 or 3 cm. of the head of the pancreas which is enlarged and increased in consistence. The rest of the head of the pancreas and, in fact, the balance of the organ as a whole are of normal consistence. Microscopic examination of tissue removed from various parts of the tumor shows the presence of a richly cellular and abundant connective-tissue stroma, scattered through which are innumerable acini of variable shapes and sizes. The individual acinus is lined by a single row of high cuboidal or low cylindrical epithelium, the cells being arranged on their basement membrane in more or less regular fashion. In some instances, however, the cells are heaped up into rows of two or three, while in other instances they may be so abundant as completely to fill the lumen, and thus to appear as a solid mass of cells. Although the histology of the tumor is characteristic of the cylindrical-cell adenocarcinoma springing from the pancreatic ducts and reproducing them in typical fashion, the presence of a large mushroom-like tumor projecting itself into the lumen of the duodenum and simulating a primary growth of that region is, in my experience at least, a most unusual finding, and constitutes perhaps, the outstanding feature of this particular case."

Comment on Cases 1 and 2.—Case 1 is apparently one of a primary carcinoma of the duodenum that was mistaken for a duodenal ulcer; case 2 comes nearer to establishing proof that a duodenal ulcer may develop into carcinoma than has any case yet reported. When the growth was carefully studied, however, it was thought in all probability to have arisen from the pancreas and to have invaded the duodenum secondarily.

CASE 3.—A man, aged 42, was admitted to the clinic on June 30, 1928, having complained of pain in the epigastrium for the past year and a half. This pain had been coming on two hours after meals, and was occasionally relieved by the taking of food. It had spontaneously disappeared at intervals of from several weeks to several months. In January, 1928, he had been operated on for an epigastric hernia which was thought to be the cause of his abdominal pain, as the results of two roentgenologic examinations of the gastro-intestinal tract had been pronounced negative, but the pain was not relieved. One month after being discharged from the hospital he was reexamined roentgenologically, with negative findings. Examination on June 18 revealed a pyloric ulcer, and the patient was admitted for treatment. He was put on an ambulatory Sippy regimen and given nonspecific streptococcus vaccine every week, the dose being increased to 1.5 cc. He progressed fairly satisfactorily after the first two months of treatment and was greatly improved symptomatically six months after treatment was started. Roentgenologic examination on May 27, 1929, revealed an ulcer at the pars pylorica and pars media on the lesser curvature, but the pyloric ulcer was not found. This examination was repeated one week later, and the ulcer which was originally reported at the pylorus was pronounced healed. The patient left the city one month later and began having increased epigastric distress. He was admitted to St. Vincent's Hospital, Worcester, Mass., and roentgen examination revealed a gastric lesion at the junction of the pars media and the pars pylorica. He was operated on on July 18, 1929, with the following findings: "An ulcer with the thick rim and crater the size of half an English walnut was found at the middle of the lesser curvature with large indurated glands in the lesser omentum, which were firmly attached. The lesion was considered malignant and inoperable; so an anterior gastroenterostomy was done."

The patient returned to the clinic two months after being discharged from the hospital and was followed until Dec. 4, 1930. During this time he had remained in excellent general condition, but roentgenologic study of the stomach revealed a carcinoma which was progressing in size. However, the patient was maintaining his weight when last seen.

Comment.—This case illustrates two very important points: (1) the difficulty of demonstrating the ulcer which was undoubtedly present when the three negative roentgenologic examinations were made, and (2) the fact that a carcinoma may develop in a stomach which has been the site of an ulcer, but quite independently of the ulcer.

CASE 4.—A man, aged 38, was admitted to the clinic in June, 1928, complaining of abdominal pain and stating that he had been treated for ulcer of the stomach. The past history was unimportant. The patient stated that in 1922 he was having pain after meals, which was growing progressively worse. At that time he entered the New York Hospital and was examined roentgenologically and treated by means of diet for four weeks. Roentgen examination at that hospital revealed a duodenal

ulcer. Since then he had been under the care of numerous physicians and had obtained some relief, at intervals, but his condition had gradually become worse. Roentgenologic study of the gastro-intestinal tract on April 20, 1928, showed that the stomach was normal but that there was an ulcer of the first portion of the duodenum with partial obstruction. The patient, after being put on a bland diet and given nonspecific streptococcus vaccine, showed definite improvement. Roentgen examination was repeated at four different times during the treatment; at all of these examinations the stomach was found normal and the lesion was demonstrated in the duodenum. In July, 1929, he returned to his native country, Poland, for three months, symptomatically greatly improved but not entirely well. While away he began to have pain in the stomach, and he returned to the clinic in November, 1929, at which time he had lost 20 pounds (9 Kg.) in weight and was still complaining of pain. Roentgen examination revealed a carcinoma of the stomach at the junction of the pars media and pars pylorica. At operation, in December, 1929, a carcinoma was found involving the entire stomach from the esophagus to the duodenum. It apparently arose at the junction of the pars media and pars pylorica. A gland was taken for biopsy, which revealed adenocarcinoma.

CASE 5.—A man, aged 52, was admitted to the clinic on July 2, 1930, having complained of pain after meals for four or five years. Roentgen examination on June 25, 1930, revealed an ulcer at the junction of the pars media and the pars pylorica. The patient was given an ambulatory Sippy diet and Saunders vaccine and became symptomatically well within two months. On Oct. 1, 1930, roentgenologic study of the stomach gave negative results. On Jan. 16, 1931, the results were again negative, but the patient had some pain in the abdomen. On April 10, however, he complained of definite pain after meals, and roentgen examination on May 6, 1931, revealed a deformity at the pyloric end of the stomach suggesting carcinoma. Reexamination on June 4 revealed a definite carcinoma of the stomach. Operation was performed on June 8. An indurated area was found on the posterior portion of the pylorus. The stomach was freely movable, and there was no evidence of involvement of the liver. The gastrocolic and gastrohepatic omenta were freed, and the duodenum was resected and closed with three layers of Pagenstecher sutures. About one half of the stomach was then excised, and the jejunum was brought through the transverse mesocolon and anastomosed to the lower end of the stomach, according to the Finsterer technic, with two rows of no. 1 chromic catgut posteriorly and three rows anteriorly. After the anastomosis had been completed, the opening in the transverse mesocolon was sutured to the stomach with three Pagenstecher sutures. The anastomosis between the stomach and jejunum lay easily without tension. The abdomen was closed in anatomic layers.

When the specimen was inspected an ulcerated area was found on the pylorus which could easily be an ulcer or an early carcinoma, but my impression was that it was purely inflammatory. On the lesser curvature, about 2 inches (5 cm.) from the other lesion, an indurated area was found which gave every appearance of being a healed ulcer, and this apparently was the first lesion from which the patient had suffered. It had entirely healed under medical treatment, the pyloric ulcer being of recent origin. The pathologic report was peptic ulcer without evidence of malignancy.

Comment.—This case revealed an ulcer at the junction of the pars media and the pars pylorica which healed under medical treatment; the ulcer at the pylorus was a separate lesion and was mistaken for an early carcinoma at roentgen examination. Histopathologic examination

of the ulcer failed to reveal any evidence of carcinoma, and even though it had been proved to be carcinoma it would not have borne any relation to the original lesion of the pars media and the pars pylorica.

SUMMARY

It is apparent that there is a great diversity of opinion among pathologists as to the percentage of gastric ulcers in which carcinomatous changes develop. If one follows cases over a long period, as Balfour did, it is seen that only a small percentage of patients actually die of carcinoma when the gastric lesion is not removed, although in Balfour's cases the lesion was of considerable size at the time of the operation. The cases reported from our clinic illustrate how unfair it is to draw the conclusion that carcinoma has arisen in an ulcer for which the patient had previously been treated, unless the original roentgenologic findings have been obtained for review and comparative study. It is my feeling that carcinoma rarely develops from a gastric ulcer, and that conservative treatment may be employed without fear of carcinoma developing from an ulcer except in a small percentage of cases. I would maintain that a gastric ulcer is not a true indication for subtotal gastrectomy, if the argument for this procedure is prophylaxis against carcinomatous transformation in the existing gastric lesion.

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A REVIEW OF UROLOGIC SURGERY

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Stone.—Violle [1] stated that of the three kinds of urinary stones, oxalatic, uretic and phosphatic, the phosphatic stones are by far the most common. The former two types are influenced by general metabolic conditions, but this is not always true of phosphatic lithiasis, since local conditions may of themselves suffice to produce it. Phosphatic lithiasis may complicate both the other types or may replace them. Then a slow and rather restrained lithogenic process may be transformed into a rapid and active one. Two conditions are necessary for such lithiasis: precipitation and the compaction of the substance precipitated. These processes occur at two different times.

Precipitation is in great part a function of urinary reaction, and is chiefly a question of hydrogen ion concentration. For precipitation a certain amount of calcium diphosphate must be present, which cannot exist unless the p_H rises above 6. When the urine is hyperacid, it contains monometallic phosphates, but very little of the bimetallic phosphates. The monometallic phosphates are very soluble; hence for p_H on the acid side of neutral there is no possibility of precipitation of phosphate. But as acidity diminishes, bimetallic phosphorus increases,

1. Violle, P. L.: Contribution à l'étude de la lithiase phosphatique urinaire, Presse méd. **40**:236 (Feb. 13) 1932.

and this may be only slightly soluble, depending on the quality of the phosphates. If they are disodic or dipotassic, they are not harmful, but if they are alkaline, for example, dicalcic, they are only slightly soluble. The danger zone for dicalcic phosphaturia begins above p_H 6, which the author calls the zone of calcium phosphate lithiasis. The p_H of the urine varies greatly in twenty-four hours. When it is in the danger zone, little variation from the usual dietary regimen, such as slight indigestion, is sufficient to cause sudden precipitation. Lactescent urine may form in the kidney, but especially in the bladder; hence phosphocalcic lithiasis is chiefly a vesical lithiasis. In the bladder urine rich in calcium may be mixed with hypo-acid urine; then immediate precipitation occurs. Sodium diphosphate, by double decomposition with neutral and soluble calcium salts, forms insoluble calcium diphosphate.

Alkalinity of the urine may be due to septic or aseptic causes. The former are well known, the latter less so. Aseptic causes are a vegetarian diet and hyperchlorhydria. The hyperchlorhydric subject normally has acid urine one hour before eating. But after eating, the gastric hypersecretion places the urine in the danger zone of phosphocalcic precipitation; the urine is at its limit of solubility, and with one step more passes the mark. This step is taken when the alkaline wave appears about four hours after a meal has been ingested following the crisis of hyperchlorhydria. At the time of the crisis, the urine is still clear; half an hour later it is flocculent, with flakes of phosphorus in suspension.

The precipitation has this special feature. Owing to its prolongation it occurs not only in the bladder but in the kidney, as is shown by pain in the kidney experienced by patients at certain hours of the day or night, corresponding to an elevated p_H. The pain may be acute, like renal colic, and be accompanied by the emission of phosphocalcic flakes or even small calculous concretions. On the other hand, the pains and flakes disappear together so that one fact becomes evident; namely, that in a number of subjects with hyperchlorhydria, phosphocalcic precipitation occurs at the level of the kidney.

The cause of lithogenesis following precipitation is inflammatory irritation in septic cases and crystals in aseptic cases. Crystals are rarer than in oxalate or uric acid lithiasis. There is one variety of calcium phosphate lithiasis associated with profound disturbance of calcium metabolism; namely, that in which the calcium in the blood is increased. The cause must lie in avitaminosis or in a functional disturbance of the parathyroid glands. At any rate, irritation by crystals provokes desquamation and an exaggerated mucoserous secretion, to which erythrocytes may be added. This exudate and desquamation form a sort of agglomeration with the precipitated salts. Thus microbes, erythrocytes, leukocytes and cellular débris are points around which precipitated salts may

collect. Almost always in the center of calculi organic elements may be found.

Treatment consists in rendering the urine sufficiently acid to prevent precipitation, in giving as little calcium as possible in the diet, in prescribing no organic acids and in the use of muscular exercise. If the urine is antiseptic treatment should be continued, and the hydrogen ion concentration determined frequently.

[COMPILERS' NOTE.—Violle's explanation of the cause of phosphatic lithiasis closely parallels that of Eisenstadt, who stated his belief that phosphate stone arises chiefly from the effect of urea-splitting organisms which raise the hydrogen ion concentration of the urine to a high alkaline level. Eisenstadt consistently found bacteria in the nucleus of phosphatic stones examined by the method of Hellström. This coincides with the views advanced by Violle.

It is felt, however, that considering the whole range of chemical precipitates involved in various types of calculi and the wide variations of the hydrogen ion concentration of the urine in health and disease, when concomitant lithiasis is not present, some other factor must be sought in the formation of stone. The present tendency to overlook a disturbance of the protective colloids of the urine as a factor in lithiasis is untenable if one remembers the work of Lichtwitz and Schade in producing calculi in vitro, and the experiments of Keyser who produced experimental calculi in animals and traced the morphologic relationship of their component crystals to the urinary colloids.]

Beer [2] stated that before analyzing the problem of recurrent calculi in the urinary tract, one must distinguish between genuine recurrences and false recurrences; the latter are due to overlooked smaller or larger fragments which have been allowed to remain in the kidney following what appeared to be complete surgical evacuation. The modern development of the surgery of renal calculi, controlled by roentgenologic examination of the exposed kidney in the operating room, has made it possible to empty the kidney more completely than before this procedure was introduced. Fluoroscopic control of the exposed kidney has proved less satisfactory than photography on a small film with an intensifying screen. Beer further explained that in addition to this control in the operating room, it is customary to take a series of flat roentgenograms before the patient is discharged from the hospital, in order to confirm the findings in the operating room. He stated that if all stones or fragments of stone are not removed, and unless one is certain that the kidney is emptied, consideration of the incidence of true recurrence is of questionable value. However, if all stones have been removed and

2. Beer, Edwin: Ann. Surg. **96**:136 July) 1933.

in the course of months or years a stone develops in the kidney, then it is a true recurrence.

If infection sets in, a totally different type of stone forms in the urinary tract, kidney or bladder, or in the gallbladder. In these observations concerning the urinary bladder, stagnation of urine seems to be the clue to the formation of stones, and it is likely that similar stagnation in the pelvis and calices of the kidney may contribute to the formation of primary uric acid, oxalate or phosphatic stones. As a result of infection, stones of earthy phosphates are most likely to develop, and the problem is to control both stagnation and infection in the kidney, if recurrent stones are to be avoided. Beer found that in the lowest calix, perhaps owing to the upright position of human beings, stones seem to form more commonly than in the other calices, either as primary stones in the calix or as extensions from a pelvic stone.

It is Beer's opinion that if deformity of the kidney and poor drainage are not controlled, dietary measures for controlling recurrence of stones seem to be of little value. Uric acid calculi, which are present in between 6 and 10 per cent of all cases, probably can be controlled by diet. Phosphatic primary stones possibly can be controlled by making the urine highly acid. Oxalate stones cannot be prevented with any regularity by a diet low in oxalate, although it is well worth while to advise the patient to avoid foods rich in oxalates. Cystine stones also are hard to control, although it has been suggested by some observers that alkalization may prevent reformation after removal of such stones. Recurrent stones in infected kidneys are much more difficult to control; even with pelvic lavage and the use of antiseptics one cannot with any regularity control reformation. However, at operation, free drainage must be established from the kidney, and if possible, if a dilated calix is found, for instance in the lower pole, this pocket should be obliterated either by using mattress sutures or by resection of the lower pole if the calix is very large. It is doubtful if nephrostomy with irrigation is of value in preventing recurrence in the presence of infection. It seems more advisable to rely on natural diuresis and the use of forced fluids to attempt to wash out the renal cavity than to rely on occasional irrigation through the cortex or through the ureteral catheter. However, in some cases in which much sand has been encountered, postoperative irrigation of the kidney through the nephrostomy tube with weak antiseptic solutions, such as hydrochloric or acetic acid, may dissolve some of the earthy phosphates and thus delay recurrence of stone.

Beer states that results of experiments with phosphatic deposits following cystotomy have been much the same. The experiments are difficult to control unless the urine is acid, and it has been found that the best acidifier is 10 grains (0.64 Gm.) of boric acid and sodium benzoate with 10 grains of methenamine, to which ammonium chloride

can be added as required. In addition, in some of the more obstinate conditions, hydrochloric acid and acetic acid in solution as high as 1:1,000 or a buffer mixture containing the sodium and calcium salts or lactic acid have been used successfully.

Randall [3] explained that among the various urinary concretions which are known to occur, there is some understanding of causative factors of only one variety. This is the so-called earthy or triple phosphatic stone. It has been recognized for some time that certain bacteria have a limited range of chemical reaction in which they normally thrive. Nowadays all bacteriologic mediums are titrated to determine their hydrogen ion concentration in order to cultivate organisms successfully. If their cultural habitat is changed in this one factor, bacteriostatic or bactericidal action is obtained. Surgeons have long trusted to iopax as a urinary antiseptic, and in order to insure the generation of formaldehyde, an acid medium is necessary. For this purpose, acidifying drugs are given by mouth to produce an acid urine.

There is a recognized group of organisms which have the power of breaking down urea in the urine with the formation of ammonia; Staphylococcus, certain strains of Bacillus coli, B. subtilis and B. alcaligenes are characteristic of this group. They create alkaline urine by their ability to split urea, and having created their ideal habitat, they thrive therein. With the formation of alkaline urine, there is a resultant precipitation of the alkaline inorganic salts of calcium, magnesium and ammonium, of which the characteristic phosphatic calculi are formed. Here, Randall stated, is a clear insight into this probable etiologic factor. Such phosphatic calculi have three characteristics: (1) They are the most rapid-growing stone seen; (2) once their deposition starts. they are rarely superseded by the precipitation of other urinary salts, and (3) they are the stones formed by the chronic stone-producers.

Randall undertook in his clinical work so to change the reaction of the urine that bacterial growth and precipitation of phosphates would be inhibited or prevented.

Randall first applied such measures in the treatment of patients who had undergone cystotomy, and there was subsequent drainage through suprapubic fistulas. These patients had undergone prostatectomy, and their wounds had broken down. The wounds in these cases seemed to be related to alkalinization of the urine. At their worst they presented ugly, sloughing, gangrenous sores, on the walls of which, and even on the abdominal skin, there were likely to be encrustations of phosphates. Such encrustations could be dissolved by topical application of a 5 or 10 per cent solution of phosphoric acid, and the wound

3. Randall, Alexander: Recurrent Calculi in the Urinary Tract, Ann. Surg. **96**:133 (July) 1932.

took on a healthy appearance. In these cases an ammoniacal odor is a forewarning that the wound may break down.

Second, Randall applied slightly different measures in cases in which breaking down of the wound had been prevented, but a threat of injury to the wound remained in the form of a persistent pool of alkaline urine. Acidifying drugs given by mouth or topical applications to the orifice of the fistula were not adequate. Consequently, he irrigated the bladder with a 1 per cent solution of phosphoric acid. Such a solution was not irritating, and even a 2 or 3 per cent solution could be used without marked irritation. Following irrigations of the type described, normal acidity of the urine in the bladder returned; thereafter, this acidity could be maintained by administration of acidifying drugs by mouth.

Randall stated that this finding naturally led to the attempt to accomplish the same results in cases of recurrent calculi in the upper part of the urinary tract. As he stated, the stones which form in these cases practically always are phosphatic, and with this in view, he reported 3 cases in which he had irrigated the renal pelvis postoperatively with a solution of phosphoric acid in the hope that by so doing infection with the organisms which have the characteristics described might be avoided. If development of these organisms could be prevented, a means would be secured toward the prevention of recurrent calculi in the upper part of the urinary tract.

Randall experimented on dogs' kidneys by injecting 1, 3 and 5 per cent solutions of phosphoric acid through the ureter from a laparotomy incision. One kidney was removed immediately, and the second one at the end of forty-eight hours. He had not been able to demonstrate, on microscopic study of these kidneys, any evidence of injury to the epithelial lining of the pelvis or to the renal papillae. There was no evidence in these sections of any caustic action from the use of the drug in these strengths. In summarizing, he stated that phosphoric acid, 1 per cent, has a hydrogen ion concentration equivalent to tenth-normal hydrochloric acid or approximately a p_H of 1.5, and on this bactericidal value is based the statement that phosphoric acid, 1 per cent, is practically isotonic and is approximately equivalent to a gastric acidity of 100. He concluded that the dissolution of small phosphatic calculi, or of fragments left at operation, may be expected because of the recognized action of such strengths of phosphoric acid in vitro and the tolerance to such topical applications in vivo.

Papin [4] analyzed 136 cases of renal lithiasis. The indications for radical and conservative operation are outlined. Nephrectomy was performed on 65 patients, conservative operations on 64, and all types of

4. Papin, E.: Etude sur la chirurgie de la lithiase rénale et en particulier sur les méthodes conservatrices, Arch. d. mal. d reins **6**:493 (May) 1932.

intervention were contraindicated in 7 cases. In 5 of 9 cases, death was due to operative shock following the removal of large infected kidneys; death in 1 of the others was due to pulmonary congestion, rupture of an abnormal artery and fistula of the small intestine. Nephrectomy was indicated for the following conditions: hydronephrosis in 17 cases; calculous pyonephrosis in 11; coralliform stones in 16; large stones in 6 and multiple stones in 6; pyelotomy impossible and nephrectomy dangerous in 2, and atrophic kidney, retrorenal abscess with an infected kidney, pelvic kidney, horseshoe kidney with a fistula, fistula persisting after nephrotomy, rupture of the ureter and rupture of an abnormal renal vein in 1 case each. These indications depended on the integrity of the opposite kidney, which must have good functional capacity without signs of lithiasis, although this last requirement was not absolute. As long as nephrotomy was the conservative operation most often performed, it was rightly regarded as more dangerous than nephrectomy, but today pyelotomy is used much more commonly, and even when nephrotomy is done it is no longer necessary to have recourse to large renal incisions, owing to the use of roentgenography and pyelography. Four of the 64 patients treated conservatively died; 3 of these deaths occurred in the series of 12 cases in which nephrotomy was performed and 1 death occurred following pyelotomy, with suppuration of the kidney, which required secondary nephrectomy; this represented 1.9 per cent of the 52 cases in which pyelotomy was carried out. In 1 case hemorrhage from the wound and in 1 case repeated internal hemorrhages occurred eight and fifteen days respectively after operation. Recurrence on the same side was observed in 5 cases, three, five and six years respectively following operation, and recurrence on the opposite side in 1 case after a lapse of ten years. Bilateral calculi occurred in 3 cases, and the intervals between operations on the two sides were four months, ten years and one year, respectively.

The procedures that made this conservative operation possible were: (1) complete roentgenographic exploration, by means of both ascending and descending pyelography; (2) an incision of limited scope; (3) improved methods of suture, and (4) replacement of the kidney by means of nephropexy over pledgets of adipose tissue.

Various types of incision were used. In 10 cases pelvionephrolithotomy was carried out with good results. In several cases, the lower pole of the kidney was freely incised and the incision prolonged, when necessary, over the inferior margin of the large lower calix. In other cases the parenchyma was incised along the oblique fold which forms a continuation of the posterior lip of the hilus; this was done sometimes before and sometimes after the pelvis was opened, and by two different technics: a free incision from outside inward, or passing a blunt Reverdin needle between the posterior surface of the pelvis and the large

lower calix on the one hand, and the wall of the sinus on the other, then through the parenchyma, carrying a silkworm suture which was pulled through the parenchyma. Such an incision seldom bled, and catgut sutures over pledgets of fat gave satisfactory hemostasis.

Small incisions of the pelvis itself do not require sutures, but if pyelonephrectomy requires a large incision, Papin always sutures the pelvis first and then the parenchyma above it.

In many cases in which there were small stones, without much infection, the pelvis was left open and the renal fossa was drained, but in the majority of cases transrenal drainage was established. Fixation of the kidney is important. Papin always replaces the organ in a high position, suspending it hammock-fashion by means of its capsule. Whenever the kidney was genuinely movable, he performed a nephropexy at the upper pole.

[COMPILERS' NOTE.—In general, the material presented by Papin brings out several features of renal lithiasis: 1. Early recognition of the disease is associated with a more conservative operative procedure which may be undertaken with slight risk. 2. In a variable number of cases (from 4 to 20 per cent), depending on the chemical type of the calculus and the nature of the infection, renal lithiasis is recurrent, and prophylactic treatment against recurrence over a period of years must be carefully carried out. 3. The author advocates surgical drainage of the kidney and its fixation in a position to insure adequate physiologic drainage, for these features constitute pertinent factors in restoring the kidney to an uninfected state and to a maximal degree of functional capacity. 4. The selection of cases for nephrectomy or for a conservative operation will depend on surgical judgment in each instance. 5. Papin's estimate of good results followed cases in which conservative incision of the kidney or renal pelvis was undertaken. His criteria for nephrectomy are well founded. Furthermore, they are consistent with the clinical judgment of most urologists, in spite of the present-day well merited emphasis placed by American surgeons on conservative renal operations.]

Woytek [5] stated that "pseudonephrolithiasis" is the term applied by Allemann to that syndrome in which the symptoms are caused by organic inflammatory kinks and strictures in the upper part of the ureter, causing disturbances in function. Such cases simulate closely the cases of true stone, since colic and microscopically observed hematuria are often present. The cause is usually an inflammatory process in the perirenal tissue or the kidney itself. Movable kidneys are associated with only a small number of cases.

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5. Woytek, G.: Über "Pseudonephrolithiasis," Beitr. z. klin. Chir. **156**:389, 1932.

Woytek has observed 60 such cases since 1924, and has divided them into two groups: that in which the onset is sudden and that in which the onset follows influenza, scarlet fever, diphtheria, puerperal sepsis, otitis media, dental infections, enteritis, salpingitis, prostatitis and seminal vesiculitis. The characteristic findings seem to be a round cell infiltration in the mucosa and musculature. Absolute proof of ureteral stricture or kink is best demonstrated by retrograde ureteropyelograms. Intravenous urography can be of secondary help.

Treatment is chiefly conservative. In cases in which the ureters show irreparable injury, it may be necessary to perform nephrectomy.

Hydronephrosis.—Walters [6] stated that conservative procedures, such as resection of the renal pelvis, reimplantation of the ureter or removal of obstructions such as peripelvic connective tissue, are strikingly indicated if hydronephrosis is bilateral, and, if unilateral, when sufficient renal parenchyma remains to justify its preservation. The safest and best procedure is the one which produces adequate and complete relief of the obstruction, with only a minimal disturbance of renal, pelvic or ureteral tissue.

Most cases of hydronephrosis are the result of definite obstructions at the ureteropelvic juncture, which in Walters' experience, have consisted for the most part of: (1) anomalous renal blood vessels, (2) peripelvic connective tissue causing angulation and collapse of the ureter, (3) narrowing of the ureter at the ureteropelvic juncture from subepithelial fibrosis and (4) incomplete obstruction of the ureteropelvic juncture owing to lateral insertion of the ureter.

The methods of treatment which were used by Walters in a series of 13 cases and which form the basis of his paper consisted of: (1) division of peripelvic connective tissue which was causing angulation and collapse of the ureter; (2) removal of the ureter from its lateral insertion in the pelvis and its reimplantation in a dependent portion; (3) transplantation of the ureter to a position away from an anomalous renal vessel that is too large to sacrifice, and (4) resection of the renal pelvis, the distended, enlarged pelvis being removed in such a fashion that when resutured the ureter is made to assume a dependent position.

In 5 cases, hydronephrosis was bilateral. Two of the patients successfully underwent bilateral renal pelvic resection, one patient more than three years ago, and the other more than a year ago. Both have been in excellent health since the operation, without evidence of obstruction of the urinary tract. In the other 3 cases, operative procedures have been applied only to the kidney which gave symptoms of obstruc-

6. Walters, Waltman: Resections of the Renal Pelvis and Other Plastic Operations for Hydronephrosis; End-Results in 13 Cases, Surg., Gynec. & Obst. **55**:508 (Oct.) 1932.

tion and which displayed the largest degree of hydronephrosis. Equally good results have been obtained in these cases. The remainder of the cases in this series were of unilateral hydronephrosis.

Postoperative complications which are likely to occur are: (1) retention of urine within the renal pelvis, which can be controlled by the temporary use of an indwelling ureteral catheter; (2) pyelonephritis, which has been controlled by intravenous administration of neoarsphenamine and mercurochrome; (3) extravasation of urine about the kidney from the line of anastomosis, and (4) the development of cortical abscesses secondary to pyelonephritis. If the last condition develops, nephrectomy at the earliest possible moment should be performed.

Tuberculosis.—De la Peña and de la Peña[7] in a review of 325 cases of renal tuberculosis reported that they have found 22 cases of complete ureteral obstruction (6.7 per cent). All of the patients except 1, from whose opposite kidney considerable evidence of infection with acid-fast bacilli also was obtained, were subjected to nephrectomy, without resulting fatality. During the last six years the authors have observed 2 cases in which autonephrectomy was produced following surgical procedures for different conditions. Nephrectomy was performed in both, without fatality.

E. de la Peña undertook experimental studies on autonephrectomy. In rabbits and female dogs, occlusion of the ureter was produced by means of ligature and endoscopic electrocoagulation respectively. Thirty or more days after the experimental occlusion, nephrectomy proved to have been a very safe procedure. From this experimental study it was inferred that endoscopic electrocoagulation, with a moderate spark and low milliamperage, for the purpose of causing occlusion of the ureter, was a safe procedure. Only one dog died; this death may be attributed to the fact that experiments were being performed to learn the greatest spark intensity that could be used, and consequently the technic was faulty. Peritonitis ensued, and death followed. After these studies the authors had the opportunity to apply the conclusions they had reached in 2 cases of renal tuberculosis. The ureters were occluded by fulguration from two to three weeks prior to nephrectomy; in both cases good results were obtained.

The possible dangers attendant on the production of ureteral obstruction by means of electrocoagulation are lessened by leaving a ureteral catheter in place for a few days. Once the acute signs of congestion produced by the electrocoagulation are past, the catheter may be removed, and contraction of the cicatricial scar will slowly pro-

7. de la Peña, Alfonso, and de la Peña, Emilio: Artificial Occlusion of the Ureter Previous to Nephrectomy in Early Renal Tuberculosis; Preliminary Report of Experimental and Clinical Study, J. Urol. **28**:343 (Sept.) 1932.

duce occlusion of the ureter. If electrocoagulation of the intravesical portion of the ureter is insufficient, the flow of urine may prevent its closing. In such a case, two or more treatments by electrocoagulation will bring about closure. If complete occlusion of the ureter from the infected kidney is induced, the bladder and genitalia are protected from infection. Also, the other kidney is protected from infection by reflux from the bladder. The condition of the bladder seems to improve after closure of the ureter. This occlusion is apparently an aid to the development of compensatory hyperfunction of the remaining healthy kidney previous to nephrectomy in cases of unilateral renal tuberculosis. It seems to diminish the risk of death from nephrectomy, and it also seems to be the best treatment for tuberculous cystitis in unilateral renal tuberculosis. Sudden hydronephrosis and pyonephrosis are possible dangers; peritonitis, if the technic is faulty, is a more remote danger.

Lieberthal and von Huth [8] stated that physiologic excretion of bacteria by the kidney does not occur. Some bacteria may pass through the kidney and appear in the renal tubules after severe renal injury, such as rupture of blood vessels, severe epithelial degeneration or glomerulonephritis, has been produced by the organisms and their toxins. The authors stated that bacilli of tuberculosis do not pass through the kidneys, from the blood into the urine, under any circumstances because of the comparatively mild immediate action of that organism on the renal tissues. Bacilli of tuberculosis rarely appear in the renal tubules, and then only as the result of a direct extension of a tuberculous lesion through the wall of Bowman's capsule or the wall of the tubule. They also stated that "true" excretion tuberculosis never occurs in the kidney, and "false" excretion tuberculosis occurs relatively seldom. Tuberculous lesions in the medulla of the kidney are usually hematogenous. Previously induced traumatic, degenerative or inflammatory lesions of the kidney do not make that organ permeable for bacilli of tuberculosis. Tuberculous lesions in the renal parenchyma which do not communicate with the renal pelvis seldom, if ever, give rise to bacilluria.

The kidney has a peculiar immunity to hematogenous infection with bacilli of tuberculosis because of its copious blood supply and the comparatively large caliber of its blood vessels. Bacilli of tuberculosis which are circulating in the blood tend to pass through the circulation of the kidney to lodge in other organs. Infection of the kidney occurs only if local disturbances in the circulation or the presence of the bacilli of tuberculosis in larger masses which cause embolism allows the organism to lodge in the renal tissues. Tuberculous nephritis does not exist.

8. Lieberthal, Frederick, and von Huth, Theodore: Tuberculous Bacilluria and Excretion Tuberculosis: Experimental Study, Surg., Gynec. & Obst. **55**:440 (Oct.) 1932.

Day [9] stated that when a tuberculous lesion has advanced to the renal pelvis or collecting tubules, renal tuberculosis never completely heals because of the handicap of hindered drainage and back pressure owing to tuberculous changes in the ureteral wall; that is to say, aside from other possible reasons, a tuberculous kidney excreting bacilli of tuberculosis cannot heal because an incurably strictured ureter interferes with normal drainage and peristalsis. When complete healing does occur, the tuberculous process is limited to the cortex. Day further stated that until the tuberculous process has extended to a calix or the collecting tubules, pus and bacilli of tuberculosis of renal origin will not be found in the urine, and therefore, up to this time, renal tuberculosis cannot be said to have been "clinically established."

Ptosis.—Braasch [10] stated that when nephropexy was so widely employed about twenty years ago, cures were claimed as a result in a variety of complaints and conditions, varying from backache to insanity. In recent years, renal fixation has been revived by the urologist, and many different attitudes exist regarding the surgical treatment of ptosis of the kidney. The two extreme views are that surgical treatment is never indicated, and that in most cases of nephroptosis operation should be performed. Adherents to a third view are of the belief that suspension of the kidney is indicated in selected cases only, but there is considerable difference of opinion as to methods of selection and as to the proportion of patients who should be so treated. The liberal members of the group would include many cases with symptoms referred to the kidney, whether or not there is evidence of pyelectasis or urinary retention on urography. The conservative element does not consider operation advisable unless there is definite urographic evidence of renal obstruction, as well as pain referred to the region of the kidney.

Pyelectasis and renal stasis should be the indications for operation and not the degree of ptosis as shown in the urogram. The importance of correct interpretation of the urogram is evident in the selection of patients for nephropexy. In extreme cases pyelectasis is easily recognizable.

Subjective relief should not be relied on unless a year or more has elapsed since operation. At the end of this time, in most cases, either the symptoms will have returned or other symptoms of a similar nature will have appeared. Urographic studies should be made following nephropexy in order to determine the results accomplished. If renal stasis was caused by nephroptosis, evidence of pyelectasis should be

9. Day, R. V.: Renal Tuberculosis: Why Clinically Established Renal Tuberculosis Never Completely Heals, California & West. Med. **37**:217 (Oct.) 1932.

10. Braasch, W. F.: Renal Ptosis (Editorial), Surg., Gynec. & Obst. **55**:247 (Aug.) 1932.

either reduced or entirely eliminated. Clinical examination of a considerable number of patients observed several years after operation by various surgeons for ptosis of the kidney would lead to the conclusion that the proportion of patients who obtain satisfactory relief of symptoms by renal fixation is comparatively small. Renal fixation without regard to any evidence of renal obstruction is not desirable.

Anomaly.—McNally [11] reported an additional case of unilateral renal agenesia in which the diagnosis was made clinically by cystoscopy and intravenous pyelography. Nineteen other cases were reported from the literature, bringing the total of reported cases to 466. These 20 cases are in agreement with the previous compilations in regard to the side on which the agenesia occurs most often (the kidney being absent on the left side in 15 cases), the condition of the ureter and the frequency of associated malformations. The importance of recognition of the condition before renal surgery is undertaken, is stressed.

Walters and Priestley [12] declared that in all cases in which an abdominal mass is present, a horseshoe kidney should be considered. They stated that unusual difficulty in freeing either renal pole in the course of surgical procedures on the kidney should arouse suspicion of the presence of fused kidney. Fused kidneys may be the site of any type of pathologic change that is seen in the normally developed kidney, but are more subject to diseases incident to urinary stasis. In most cases, fused kidneys lie median to the position that would be occupied by a normal kidney. Various degrees of dystopia and inclination to one or the other side may occur. Males are more commonly afflicted with horseshoe kidneys than are females. The importance of pyelographic examination before renal operation cannot be overemphasized. Alterations in function of horseshoe kidneys depend on the pathologic change present, except when one kidney suffers arrested development. The portions of the ureters that are near the bladder usually are in normal position. The mortality following operation on 50 patients with horseshoe kidneys seen at the Mayo Clinic was 2 per cent.

[COMPILERS' NOTE.—The diagnosis of horseshoe kidney was verified at operation in 68 cases observed at the Mayo Clinic; subsequent information was obtained concerning 58. Five patients had died. Of the 53 remaining patients, 25 stated that they had no symptoms referable to the genito-urinary tract, and 15 had minor complaints such as slight burning or frequency. This is in contrast to the opinion held by many urologists that these patients, after once having trouble, always retain some symptom of disease referring to the urinary tract.

11. McNally, Andrew: Unilateral Renal Agenesis, J. Urol. **28**:289 (Sept.) 1932.

12. Walters, Waltman, and Priestley, J. B.: Horseshoe Kidney: A Review of 68 Surgical Cases, J. Urol. **28**:271 (Sept.) 1932.

The morbidity of horseshoe kidney is clearly seen in the relation between its occurrence and the frequency with which it requires surgical intervention. In a collected series of 68,000 postmortem examinations Carlier and Gerard found 80 horseshoe kidneys, or 1 in every 850 subjects. In an earlier paper from the Mayo Clinic in which a ten year period of renal surgery was reviewed, 2,424 operations were performed on the kidney for various conditions; 17 of these were on horseshoe kidneys, or 1 in every 142.

Knowledge of the stages of embryologic development by which the kidneys are fused permits a better understanding of the pathologic conditions which result in later life.]

Aneurysm.—Lozzi [13] stated that arteriovenous aneurysm of the renal vessels is extremely rare, but that about 40 cases of aneurysm of the renal artery alone have been reported. In experimental work he produced a permanent arteriovenous fistula, and studied the anatomic and functional changes produced in the kidney. He established anastomosis between a renal artery and vein in twenty-four large dogs, all in good general condition. The operation was done on the right side, because access is easier there and the artery is longer. In only four animals did he succeed, however, in making a fistula which could be regarded as permanent. In some cases that were technically successful, the fistula became obliterated, either through simple occlusion of the communication or through partial or total thrombosis of the lumen of the vessels. This Lozzi attributed to the small caliber of the renal vessels. In order to control hemorrhage and obtain an immediate good result he had found it necessary to choose vessels of relatively small caliber, especially arteries, and this fact contributed greatly toward the formation and deposition of thrombi which occluded the fistula or, more often, the artery or vein in question. The best permanent results were produced when the caliber of the vessels was larger, providing wide communication without too much restriction of the lumen. It was important to make the sutures with extreme delicacy and the finest Carrel needles, so that there should be no laceration or enlargement of the opening made by them.

In every case there was diminution of the peripheral pulse, and sometimes complete obliteration. Changes of rhythm or pulse rate were never observed. On the other hand, the kidney became turgid, with a rapid increase of volume and consistence, which was sometimes of great intensity. In a few cases there was a "thrill" on palpation, with reenforced systole, above and below the fistula. When the fistula was permanent, there were changes in the caliber and structure of the vein.

13. Lozzi, Vanazio: Aneurisma artero-venoso sperimentale dei vasi renali, Policlinico (sez. chir.) **39**:357 (June) 1932.

There was always venous congestion of the renal parenchyma, but sacciform or fusiform dilatations of the anastomosis never occurred. In some cases foci of hemorrhagic infarcts occurred, owing to the ease with which small thrombi became formed and detached soon after the fistula was made; in only 4 cases was there a total infarct of the kidney.

Chief among the functional disturbances observed was hematuria of greater or lesser degree, appearing as soon as the kidney began to function and conspicuous during the first two or three days, but persisting in microscopic amount several days longer. As there were never any varices of pelvis or calices, Lozzi thought that the hematuria was always due to diapedesis. Whenever the fistula remained open, albuminuria was abundant; it lasted longer than hematuria, and, like the latter, was to be interpreted as due to congestion and epithelial degeneration, whenever it was not the expression of a hemorrhagic infarct. Cylindruria was present during the first days, the cylinders being hyaline and epithelial at first, and granular later.

All these disturbances indicated the changes undergone by the renal circulation following sudden anastomosis. The concentration of nitrogen in the blood, which in all the animals was about 0.2 mg. in each 100 cc. before operation, rose suddenly on the day following, reaching in some animals from 0.55 to 0.6 mg., and remained high for several days until renal function had improved. On the first two days after operation the vascular disturbance was so great as to stop nearly all function of the kidney. Elimination of intravenously injected sodium indigotindisulphonate U. S. P. (indigo carmine) was delayed, being prolonged sometimes from fifteen to twenty minutes on the side on which operation was performed. But the most exact expression of a change of function was given by the elimination of phenolsulphonphthalein. Although this was not delayed, elimination of the drug was deficient, the amount eliminated in the first hour being in some cases scarcely from 10 to 15 per cent. Ten cases in which the fistula became obliterated were of interest because it could be observed that the functional deficit of the kidney on operation was exactly proportional to the degree of arterial stenosis left by the operation.

Resection.—Stone [14] stated that heminephrectomy is indicated in the presence of nonmalignant changes when the disease is limited to a single section of a double kidney, and there is a sufficient secretory area in the other segment to make conservation worth while. When an embryonic cleavage plane exists between the segments, it is not necessary to compress the vessels to the segment to be left or to close the exposed surface of the remaining kidney. Stone added that it is wise to expose the entire blood supply of the double organ before resection and to suspend the remaining segment.

14. Stone, Eric: Heminephrectomy, J. Urol. **28**:301 (Sept.) 1932.

No deaths were reported in the cases reviewed by Stone. In 3 cases the remaining segments had to be removed later. In 22 of 30 cases in which heminephrectomy was performed, the symptoms which led to the operation were relieved. In 2 cases a urinary sinus persisted. Both operations were performed by Rumpell. The first of these operations was stated to be the first heminephrectomy ever performed, and it is probable that a calix was entered and the condition was not recognized; in the other case the ureter to the sound segments was accidentally destroyed, and the ureter to the diseased segment was anastomosed to the normal pelvis.

Denervation.—Lozzi [15] published follow-up data on a series of 20 patients on whom he performed renal decapsulation, and reported the late results of the procedure, which were almost uniformly good.

The kidney is innervated by a special plexus formed by fifty-six small trunks which anastomose; these run particularly on the posterior surface of the vascular peduncle, and are more or less adherent to the adventitia, thus making a large meshlike reticulum around the vessels. A second network, more delicate and fine, visible only through the microscope, forms part of the adventitia of the artery, and receives small anastomosing branches from larger superficial trunks. All these nerve fibers, joined at the renal hilus, penetrate in part into the organ, while others, corresponding to the internal aspect of the fibrous capsule, are distributed centripetally, at various intervals, in the cortical substance. These nerves, if interrupted, regenerate with marked promptitude, so that by the end of forty-five months they are completely restored.

The function of the renal plexus is to exert a lively vasomotor action on the arterial circulation of the organ. Renal decapsulation would cause interruption of all these fibers which make connection with the fibrous capsule, and would thus result in partial denervation of the kidney. A thorough search of the literature on the subject does not confirm Edebohl's view that the good effects of renal decapsulation are attributable to the development of collateral, arterial and venous circulation. If this were the case, the good effects would be observed only after the lapse of a certain period of time, whereas, on the contrary, the satisfactory results appear suddenly, immediately after removal of the capsule. Lozzi attributed them to the beneficial nervous influence exerted on the vascular system. In addition, decapsulation also concerns sensory fibers, as is shown by the large number of cases of nephralgia in which cure is effected. Not only does it produce no injurious disturbances either in the parenchyma or in function, but it

15. Lozzi, Vananzio: Risultati lontani della decapsulazione ed enervazione renale, Policlinico (sez. chir.) **39**:84 (Feb.) 1932.

even, through improved circulation, promotes a better state of nutrition and therefore of renal function. As soon as decapsulation has been performed, the kidney increases in size and assumes a more arterial color, as the result of vasodilatation, especially venous. This vasodilatation must be explained as the effect of a vasomotor influence from a nerve lesion. This view is supported by Valdon's experiments, in which vasodilatation was obtained only in the decapsulated portions.

Clinically, the hypothesis of vascular action is supported by numerous arguments, such as its immediate occurrence, explainable only by the cessation of a nervous action on the vessels, and the immediate cessation of pain in acute nephralgia, which could be the result only of destruction of the capsular sensory terminations of vascular action.

A review of the literature reveals that the results were good in the majority of cases on record. Lozzi's own 20 cases included 3 of anuria, 8 of painful hematuric nephritis, 2 of adhesive perinephritis and 2 of pyelonephritis. In 19 cases there was either cessation of the syndrome or marked improvement. The late results can also be regarded as satisfactory, since clinical cure persists in about 75 per cent. In 1 case of anuria only did death occur after operation, owing to the presence of a small calculus in the ureter of a solitary kidney which had been overlooked in the roentgenogram. Two deaths resulted from uremia one and two years respectively after decapsulation. Permanent clinical cure had been obtained in the remainder of cases. Late functional tests were perfect, after decapsulation and enervation. The rapid reestablishment of diuresis after anuria and the disappearance of the clinical syndrome in cases of painful hematuric nephritis must be regarded as due solely to a vasomotor effect exerted on the vascular system of the renal parenchyma which, through improved conditions of circulation, necessarily underwent improvement both anatomic and functional. Even in cases in which decapsulation was applied without precise indications, it produced immediate and lasting satisfactory results.

Perinephritic Abscess.—Crenshaw [16] reported 2 cases, which serve as reminders of the fact that the occurrence of a perinephritic abscess rupturing into a bronchus is rare. He reported that this complication does occur and should be thought of when a perinephritic abscess is accompanied by a cough, particularly when the patient is in the recumbent position, or by excessive sputum and elevation of the diaphragm, and conversely, that it should be considered when pulmonary symptoms are accompanied by or preceded by findings suggestive of renal disease. He stated that early diagnosis and early drainage of the perinephritic abscess would greatly reduce the pulmonary injury.

16. Crenshaw, J. L.: Pyonephrosis with Nephrobronchial Fistula, J. Urol. **28:** 427 (Oct.) 1932.

Infection.—Hyman and Edelman [17] stated that invasion of the blood stream in diseases of the urinary tract is not uncommon. Two types of infection are generally recognized: bacteremia, which is generally transitory and is attended by little if any mortality, and septicemia, which is grave and is attended by high mortality. The majority of infections of the blood stream observed by the authors were due to some form of urethral instrumentation or originated after operation. Forty-five of the 64 cases studied were due to bacillary infections, with a mortality of 20 per cent; 19 were due to coccal infections, and 68.4 per cent of the patients died. The main factor in treatment is adequate care of the primary focus of infection.

Tumors of the Renal Pelvis.—MacKenzie and Ratner [18] stated that the types of tumors that arise in the renal pelvis are similar to those that occur in the bladder. Most of them are derived from mesodermal tissue. About from 40 to 50 per cent of all tumors of the renal pelvis are papillomas. They usually are multiple and appear as villous or wartlike growths similar to those found in the bladder. Often there is one large tumor, with several smaller tumors surrounding it. Frequently these growths are associated with salty incrustations and even with definite calculi.

Papillary epithelioma comprises about from 20 to 30 per cent of the growths of the renal pelvis. These tumors are also wartlike, but appear more compact and involve a greater area than the simple papillomas. In the early stages of the growth there is definite evidence of involvement of the submucosa, and later the renal parenchyma is encroached on. In advanced cases there is usually distention of the renal pelvis, and multiple cysts are present in the cortex of the kidney. These tumors are also extremely vascular and bleed easily.

Squamous cell carcinoma comprises a small group, but a fair number of cases have been reported in the literature. The importance of previous infection as a causative agent should be emphasized. Leukoplakia with calculi also seems to play a part, as several of the cases described have been associated with these conditions. The lesions grow rapidly and involve the renal parenchyma and the surrounding tissues.

The most outstanding symptom in tumors of the renal pelvis is hematuria. Pain is not a constant symptom. At times a patient complains of a dull ache in one or the other loin. Occasionally there is typical renal or ureteral colic. This is due to the passage of a small transplant or blood clot down the ureter. Severe pain may also result

17. Hyman, A., and Edelman, L.: Medical and Surgical Aspects of Hematogenous Infections in Urology, J. Urol. **28**:173 (Aug.) 1932.

18. MacKenzie, D. W., and Ratner, Max: Tumors of the Renal Pelvis: A Review of the Literature and Report of a Case, J. Urol. **28**:405 (Oct.) 1932.

when obstruction occurs at the ureteropelvic angle, causing hydronephrosis or hematonephrosis.

In a large number of cases a mass cannot be palpated. This is particularly true when the growth is small or when it is spreading toward the upper pole of the kidney. The most common cause of a palpable tumor is probably associated hydronephrosis or hematonephrosis due to some form of obstruction.

MacKenzie and Ratner further stated that although simple papilloma of the renal pelvis is benign, clinically it is potentially malignant. It has the property of forming transplants in the ureter and bladder and even in the opposite ureter. The most malignant papilloma gives a better prognosis than other malignant growths of the renal pelvis. The most malignant tumor of the renal pelvis is the squamous cell carcinoma. It metastasizes early and extensively. The results are poor even when treatment is given early.

MacKenzie and Ratner stated in conclusion that on account of the tendency of tumors of the renal pelvis to extend down the ureter and even to the bladder, the treatment of choice today is nephrectomy and complete ureterectomy.

Pararenal Tumors.—Didier and Leibovici [19] reported 2 cases of paranephritic fibrolipomas; one tumor weighed 3.75 Kg. and the other 10 Kg. Although these tumors are very large, growths have been observed that weighed as much as from 20 to 30 Kg. They occur more frequently among women, and have occasionally been diagnosed as ovarian cysts. Histologically, the tumors are usually fibrolipomas; rarely do they become malignant; nevertheless they have a tendency to recur locally, so that even if operated on, they usually cause death from cachexia in a few years, the patient becoming emaciated as the tumor grows larger. The great size of these tumors, the plane of cleavage sometimes to be found between their several lobes, and their tendency to put forth distant prolongations make it impossible to determine whether the growth has been entirely removed. Rarely has the diagnosis been made clinically. At present it would appear that modern means of diagnosis are at hand which, if they do not permit an absolutely exact diagnosis, at least eliminate certain current diagnoses, such as ovarian cyst. Use of the barium sulphate enema would show the exact situation of the tumor relative to the colon, which these growths flatten and generally empty of gas.

The condition of the kidney is of diagnostic aid. Usually the kidney is destroyed either by the tumor or at the time of operation (removal). Consequently, the function of the opposite kidney should be determined before operation. More than half the operations for

19. Didier, Robert, and Leibovici, Raymond: Deux volumineux fibro-lipomes paranéphrétiques, Bull. et mém. Soc. nat. de chir. **58**:1068 (July 16) 1932.

pararenal tumors have ended with total extirpation of the kidney, the sacrifice of which has often been unnecessary. In many cases, the kidney is not invaded by the growth and can be separated from it and conserved; renal adhesions are usually only to the capsule. If the tumor is at points adherent to the parenchyma, it is easy to detach a small section of the renal tissue with the tumor.

The first step in the operation should be to find the ureter at the lower pole of the kidney. Whether the operation is performed by the transperitoneal route, as is occasionally done, or by the lateral subperitoneal route, the method favored by Didier and Leibovici, it should always be possible to find and isolate the upper part of the ureter. Conservation of the kidney, in fact, usually depends on the renal pedicle. If the pedicle can be isolated, conservation should be attempted, unless the kidney appears diseased. If, however, the renal vessels penetrate within the tumor, and if to conserve them one must risk performing an incomplete operation, the kidney must be sacrificed.

Differentiation of Right-Sided Renal Disease from Appendicitis.—Salleras [20] asserted that there is an extraordinary amount of confusion in the diagnosis of right-sided nephrosis and appendicitis. The type of pain and its situation are of no value for diagnosis, as they may be exactly the same. In painful renal diseases, however, there are almost never lacking such vesical reflex symptoms as pollakiuria, dysuria and oliguria which may end as the pain declines with marked polyuria and with the elimination of several liters of urine, according to the length of the attack. In appendicitis, on the contrary, nothing like this occurs. In both conditions, the symptoms are the same. The ureteral catheter will reveal a stone if it is in the urinary tract. Examination of urine from the ureteral catheter frequently reveals infections which cause pain simulating appendicitis.

The pyelogram, however, gives the most accurate differential data. In some cases it discloses slight uronephrosis caused by an anomalous vessel. A pyelogram likewise shows up stones which may be permeable to roentgen rays, thus preventing confusion. After the injection of pyelographic mediums repeated roentgenograms, taken at intervals of ten minutes, not only help in making the diagnosis, but also show the state of contractility of the renal pelvis.

The occasional renal, vesical or perinephritic complications secondary to acute appendicitis make pyelography doubly important. Salleras described cases in which the appendix was low in Douglas' culdesac and caused reflex vesical symptoms, cases in which retrocecal appendix was complicated by perirenal abscesses and cases in which a perforated

20. Salleras, J.: Uronefrosis derecha y apendicitis, Rev. Asoc. méd. argent. **46**:478 (June) 1932.

appendix was in contact with the renal pelvis. He also observed cases of hematuria secondary to acute appendicitis, in which appendectomy caused complete cure, a fact that can be explained by the action of toxins or micro-organisms which reach the kidney by way of the blood stream.

[COMPILERS' NOTE.—It seems proper to emphasize that in dealing with doubtful cases of so-called chronic appendicitis or pain on the right side of the abdomen, it should be a rule that operation should not be performed until changes in the right kidney have been ruled out by either an intravenous urogram or a complete urologic examination.]

Anomalies.—Williams [21] reported the discovery at necropsy of complete bilateral duplication of the ureters of a girl aged 18 years, who was five months pregnant. The four ureteral orifices were observed, and each of the four ureters allowed the passage of a probe. An attempt to catheterize one of the right ureters during cystoscopic examination met with obstruction after the catheter had entered about 12 cm. This proved to be due to a diminution in the caliber of the ureter and not to a mucosal fold or calculus, as suspected. This ureter was of varied caliber in several places, whereas its double was almost uniform throughout and of greater diameter, and would have received a catheter without difficulty.

Stone.—Goldman [22] reported that the specimen which he presented is one of the largest ureteral calculi described in any of the literature available to him, and that the patient is the youngest reported to have been operated on for the removal of a stone of that character and size. The stone was extracted entire from the ureter, and a small calculus adjacent was secured after some efforts with finger and forceps. Recovery was uneventful; a sinus did not develop, and the wound was entirely healed in fourteen days. The boy had gained more than 30 pounds (13.6 Kg) seven months after operation; the urine was clear, but contained a few pus cells. He had no urinary symptoms, and continued to gain in strength.

The stone weighed 125 Gm. on removal, and measured approximately 18 cm. in length and 9 cm. in circumference. Goldman also gave a good review of the literature on large ureteral stones.

Mathé [23] stated that the diagnosis of stone in the ureter can be accurately made with the perfected methods of ureteral investigation and roentgenologic study now in use. The majority of stones in the ureter

21. Williams, Pauline: Complete Bilateral Duplication of the Ureters, J. Urol. **28**:279 (Sept.) 1932.

22. Goldman, Max: Mammoth Ureteral Calculus: Report of a Case, J. Urol. **28**:371 (Sept.) 1932.

23. Mathé, C. P.: The Diagnosis and Present-Day Treatment of Ureteral Stone, J. Urol. **28**:133 (Aug.) 1932.

can be made to pass by dilation exceeding the diameter of the calculus and by incision of any accompanying congenital stricture of the meatus. The indiscriminate use of metal instruments to induce the calculus to pass may often result in injury to the ureter that exceeds the occasional immediate successful removal of the stone. The persistent use of cystoscopic manipulations to relieve impacted calculi lodged in a localized dilated portion or diverticulum of the ureter is not advisable and subjects the kidney to irreparable injury. Uterolithotomy should be performed for impacted calculi, for calculi that show no tendency to descend, for calculi in the solitary or bifid ureter and in cases in which it is impossible to make repeated cystoscopic examinations.

Pyo-Ureter.—Molina [24] reported 2 cases in which, at nephrectomy, the infected stump of the ureter was not removed with the kidney. Cases of renal tuberculosis often occur, in which the whole or part of a ureter in a pathologic condition is not removed with the kidney. Suppuration and infection continue, until sometimes it is necessary to remove the ureter at a later operation. Although nephro-ureterectomy is now an established principle in cases of renal tuberculosis in which the infection extends to the ureter, its significance has not been sufficiently recognized in other cases in which nephrectomy is performed. At times the ureteral stump becomes a hard, sclerotic cord after the passage of a certain period, but this is not always the case.

In the first case reported, the kidney had been removed because a large stone was present, but a calculus in the lower part of the ureter had been overlooked. Pyo-ureter developed, which at first discharged its content into the bladder; later the stone obstructed the ureteral orifice, and because of back-pressure and infection, an abscess formed in the wall of the lumbar region. In the second case the patient complained of intense pain; this was caused by three calculi in the lower part of the ureter.

In accordance with Jeck's conclusions, Molina stated his belief that pyo-ureter is caused by obstruction of the ureter and by lesions of its innervation, resulting in absence of peristalsis and loss of tonus. In most cases the principal etiologic factor is calculus in the ureter. This condition is best prevented by appropriate treatment of the ureter and its content at the time that nephrectomy is performed. Although in some cases methods such as fulguration and irrigation are successful, ureterectomy, especially total ureterectomy, is indicated in the majority of cases. If this is not done and an abscess of the wall with a postoperative secondary fistula develops, it is necessary to reopen the wound and to resect all the infected perirenal tissue.

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24. Molina, L. F. R.: Dos casos de pio-ureter, Ann. de cir. (Havana) **4**:457 (July) 1932.

[COMPILERS' NOTE.—It is obvious that when the ureter is involved in the pathologic process of the kidney, or vice versa, and the condition is clearly recognized before operation, the proper treatment is ureteronephrectomy. Gutierrez [25] recently reviewed the indications for ureterectomy. He considered the value and convenience of making two separate incisions in order to accomplish total removal of the kidney and ureter in one piece without opening. To obviate failure in nephrectomy, a pyelo-ureterogram should always be taken before operation. When this is not possible by either the retrograde or the intravenous method of pyelography, the urologist should be prepared to perform complete nephro-ureterectomy when indicated.]

Rupture.—Wesson [26] stated that the wall of a normal ureter cannot be punctured by a catheter, and it is doubtful if a diseased ureter can be perforated unless a deep ulcer is present. By means of necrosis caused by pressure, stones produce leaks or openings through which they penetrate, and the resultant perinephritic abscess may drain into the ureter or bowel or to the external surface.

Perforation of the ureter when it is catheterized through the cystoscope is impossible, for the catheter buckles in the bladder if the point meets with resistance. In an experimental study of specimens removed at necropsy, the bladders were finally opened and the mouths of the ureters held with artery forceps so that the maximal amount of pressure could be exerted by the tip of the catheter. The most severe test was to tie a ureter in a knot, and in no case was perforation produced by a catheter.

Fistula.—Hunner and Everett [27] reported a case of urinary ascites resulting from a traumatic fistula of the right ureter following supravaginal hysterectomy for fibroid tumors. Although the urinary ascites was present for more than a week the patient was not severely ill, and a satisfactory cure was obtained by severing the ureter at the site of the fistula and reimplanting it into the bladder. The patient has remained well since.

Hunner and Everett reported a second case, which, although different from the first both in etiology and in outcome, is reported as additional evidence that the peritoneal cavity can tolerate large quantities of urine over a considerable time without the patient experiencing any severe reaction. This case was one of carcinoma of the cervix; the patient had received radium and roentgen therapy, and later a vesico-

25. Gutierrez, Robert: Indications and Technic of Combined Ureteronephrectomy, Ann. Surg. **93**:511 (Feb.) 1931.

26. Wesson, M. B.: Rupture of Ureter: A Medico-Legal Problem; Report of Cases, California & West. Med. **37**:296 (Nov.) 1932.

27. Hunner, G. L., and Everett, H. S.: Uretero-Peritoneal Fistula with Urinary Ascites, J. Urol. **28**:333 (Sept.) 1932.

vaginal fistula and a ureteroperitoneal fistula developed. The ureters were transplanted to the colon; the patient died of uremia. Necropsy revealed generalized chemical peritonitis.

This case also calls attention, in a striking manner, to some of the late effects on the deeper tissues of the massive irradiation sometimes necessary for overcoming malignant growths. However, Hunner and Everett have previously reported on the rapidly increasing group of cases in which, following pelvic irradiation, ureteral and periureteral changes develop that lead to urinary stasis and renal injury. These investigators expressed the belief that in the future all patients who have received heavy irradiation of the pelvic organs should be advised to report at intervals of six months for careful investigation of the ureters to insure that the function of these organs is not being seriously jeopardized.

Implantation.—Green-Armytage [28] stated that since Coffey's improvements in the technic of ureterorectoneostomy which have extended the indications for the operation, a number of modifications have been reported for the purpose of simplifying this procedure. Green-Armytage reported 8 cases of bilateral simultaneous transplantation of the ureters in which he used a straight metal tube to convey the ureteral catheters through the anus. Thereby he eliminated the time-consuming preliminary irrigation of the bowel through a cannula and rectal packing through a sigmoidoscope, which was the technic used by Coffey. Green-Armytage used a metal urethral catheter the curved end of which was cut off and a straight conical screw bulb substituted. This was passed through the stab wound in the mucosa at the distal end of the incision, through the muscularis and, with the aid of a Kelly cystoscope, out of the anus. The catheter, which had been fixed in the ureter by a single ligature of 000 catgut, was passed through this metal tube, which was then removed and prepared for use in anastomosis of the other ureter.

Green-Armytage did not use the tight ligature of the ureter to the ureteral catheter, by which the ureter is cut through in several days, nor did he use the pack which Coffey thinks is so essential in all cases of bilateral simultaneous anastomosis. He reported 10 cases of severe vesicovaginal fistula, in 2 of which bilateral simultaneous anastomosis was made without using the tube technic; in the other 8 cases, his modification of the tube technic was employed.

Burman [29] reported the case of a patient with a vesicovaginal fistula whose right ureter was implanted into the cecum through the stump of

28. Green-Armytage, V. B.: Implantation of the Ureters for Inoperable Vesico-Vaginal Fistula and Ectopia Vesicae: A New Technique, Brit. J. Surg. **20**:130 (July) 1932.

29. Burman, C. E. L.: A Case of Transplantation of the Right Ureter into the Caecum and of the Left into the Sigmoid Five Years Afterwards, Brit. J. Surg. **20**:44 (July) 1932.

the appendix. Five years later the left ureter was transplanted into the sigmoid. Intravenous urograms one month after the second operation showed advanced hydronephrosis on the right side and early hydronephrosis on the left side. The patient died from an undetermined cause two months after the second operation.

[COMPILERS' NOTE.—Coffey's [30] latest contribution to the technic of ureterorectoneostomy is the transfixion suture method or technic 3. The same incision is made in the intestine down to the mucosa, which, however, is not opened. The end of the freed ureter is ligated and brought into the interlamellar space outside the intestinal mucosa by an anchor stitch which fastens the end of the ureter in the angle of the caudal end of the incomplete intestinal incision. A transfixion suture of silk or linen is then taken through the ureter and the intestinal mucosa and is tied tightly. It cuts through in from twenty-four to forty-eight hours and completes the anastomosis. Coffey reported 3 cases in which the operation was performed by this method, in one instance by Brunn and in the others by himself. Coffey's technic was employed by one of the compilers in a case of exstrophy of the bladder, and the absence of postoperative reaction as compared to that which follows when other methods are employed was impressive. Intravenous urography three months postoperatively demonstrated absence of pyelectasis or ureteral dilatation. Technic 3 is much simpler than technic 2 or even technic 1, and is an outstanding contribution to methods of diverting the urine to the bowel.]

30. Coffey, R. C.: Transplantation of Ureters into Large Intestine by Submucous Implantation: Clinical Application of Technic, J. A. M. A. **99**:1320 (Oct. 15) 1932.

(To be continued)

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